AN EVALUATION OF CONTINGENCY CONSTRUCTION METHODS USING VALUE FOCUSED THINKING

THESIS

John E. Tryon, Major, USAF

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DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY

AIR FORCE INSTITUTE OF TECHNOLOGY

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John E. Tryon, BS

Major, USAF

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John E. Tryon, BS
Major, USAF

Approved:

/Signed/	16 Mar 2005
Alfred E. Thal, Jr., Ph.D. (Chairman)	date
/Signed/	16 Mar 2005
Derek A. Jeffries, Lt Col, USAF (Reader)	date
/Signed/	16 Mar 2005
Jeffery D. Weir, Lt Col, USAF, Ph.D. (Reader)	date

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Abstract

Rapid Engineering Deployable, Heavy Operational Repair Squadron, Engineer (RED HORSE) Squadrons are 400-person self-contained combat engineer units that provide deployable and flexible expert construction capability for the United States Air Force. To help meet Air Force mission requirements, RED HORSE units currently employ a variety of traditional and innovative construction methods. But their alternatives-focused decision analysis approach to method selection limits their decision to known alternatives and may not fully achieve all of their objectives.

This research developed a generic value-focused thinking (VFT) decision analysis model to help RED HORSE evaluate and select contingency construction methods. Eight alternatives were generated and evaluated using the model, and Royal Building System's stay-in-place plastic formwork method achieved the highest total value score for the weights assigned to the value hierarchy. Deterministic and sensitivity analysis were performed on the value model results, and conclusions and recommendations were discussed.

This research showed that VFT is a viable methodology for contingency construction method selection. The value model captured RED HORSE objectives and used their values as the basis for evaluating multiple construction method alternatives. The alternatives' value score ranking results were objective, defendable, and repeatable, and the value model is highly adaptable for future contingency implementation.

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To my parents

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John E. Tryon

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AN EVALUATION OF CONTINGENCY CONSTRUCTION METHODS

USING VALUE FOCUSED THINKING

1. Introduction

This thesis researched the potential of using a value focused thinking methodology for evaluating multiple construction method alternatives for use in future Air Force contingencies. Chapter 1 introduces the concept of contingency construction in a bare base environment and explains why Air Force Rapid Engineering Deployable, Heavy Operational Repair Squadron, Engineer (RED HORSE) units are ideally suited for this important task. Chapter 1 also identifies the research problem of selecting the most appropriate contingency construction method and explains the research objective and questions generated to help solve this problem. Finally, Chapter 1 discusses the approach and scope of this thesis.

1.1 Background

Air Force Instruction 10-209 defines a contingency as "an emergency involving military forces caused by natural disasters, terrorists, subversives, or military operations." And due to the uncertain nature of contingencies, "plans, rapid response, and special procedures to ensure the safety and readiness of personnel, installations, and equipment" are required (HQ AFCESA/CEX, 2001:32). Air Force civil engineers are tasked to provide contingency construction support in a variety of contingency situations, ranging from peacetime humanitarian assistance to wartime force beddown operations. The most demanding of these situations perhaps is wartime contingency construction support at bare base locations where engineers must provide “vital equipment and supplies necessary to beddown and support combat forces at bases with limited or no facilities” (HQ AFCESA/CEX, 2001:32). Bare bases can include as little as a runway and parking ramp suitable for aircraft operations. In bare base locations, Air Force civil engineers plan, design, and construct the living and working facilities for the combat forces carrying out aircraft operations (Hartzer, 1994:2). Operations Desert Shield and Desert Storm in the early 1990’s underscored the importance of the Air Force civil engineers in providing an available, reliable, and capable network of bases to support the application of air power (Hartzer, 1994:1).

The United States Air Force (USAF) “core competencies” include air and space superiority, global attack, rapid global mobility, precision engagement, information superiority, and agile combat support. The last core competency on this list, agile combat support, is the dominant mission of Air Force civil engineers. They have the ability to quickly deploy anywhere in the world, transform undeveloped real estate into an operational air base, and provide the facility and infrastructure support required to sustain air combat operations. During Operations Desert Shield and Desert Storm, “Air Force Prime Base Engineer Emergency Force (Prime BEEF) units bedded down approximately 55,000 Air Force personnel and more than 1,500 aircraft” at various locations throughout the Southwest Asia area of operations (Hartzer, 1994:2). Prime BEEF units sustained these bases, some which began as bare bases, to varying degrees and prepared to recover them upon attack.

When a specific contingency or location requires expedient heavy construction and repair capabilities, then the Air Force relies on its RED HORSE units. Thus, Rapid Engineering Deployable, Heavy Operational Repair Squadron, Engineer (RED HORSE) units are often referred to as the Air Force’s primary contingency operations construction element. Specifically, these units “provide the Air Force with highly mobile, self-sufficient, rapidly deployable civil engineering heavy construction and repair capability” (Dept of the Air Force, 1983:6). When deployed to combat areas, they provide air component commanders with “a dedicated, flexible airfield and base heavy construction and repair capability, along with many special capabilities that allow the [combatant commanders] to move and support missions as the air order of battle dictates” (HQ AFCESA/CEX, 2001:12).

RED HORSE units are mobile 400-person combat engineer units who deploy with approximately 1,400 short tons of vehicles and heavy construction and support equipment. They are self-contained and designed to operate in deployed hostile environments with little to no outside support; besides deploying with their own construction equipment. They also bring their own weapons, food service, and medical support (Grier, 2003:1). In effect, they provide expert construction capability anywhere in the world (Andel, 1987:1).

The concept of RED HORSE units emerged during the Vietnam War, and the first two units were established in September 1965 (Hartzer, 2004:1). Over the ensuing four decades, RED HORSE achieved may successes. Their most recent successes occurred in support of Operations Enduring Freedom and Iraqi Freedom. From January 2002 through February 2003, RED HORSE personnel supported Air Force missions in Afghanistan, Qatar, Kyrgyzstan, and other austere locations. Construction projects included the largest aircraft parking ramp in RED HORSE history: 47 acres of pavement, as well as 124,000 square feet of covered aircraft maintenance space, four hangars, a warehouse, a fire station, and a squadron operations facility (Grier, 2003:1). At Bagram Air Base in Afghanistan in late 2001, RED HORSE units repaired the destroyed Soviet built runway and ramp; they also built new shower and laundry facilities and several hundred feet of security walls (Grier, 2003:2). In Oman, starting in late December

2002, RED HORSE personnel constructed a concrete aircraft parking ramp equal in size to 36-football fields (Gomaco World, 2003:3).

RED HORSE units overcame several unique challenges during these contingency operations. First, to support and enable such large construction efforts many tons of materials and equipment had to be transported by airlift and sealift to overseas, often remote locations. Heavy construction equipment such as slipform paving machines and concrete laydown equipment were delivered from the United States on commercial Antonov cargo planes (Gomaco World, 2003:3). Other materials and equipment were transported by truck and C-130 aircraft between various locations within the area of operations. Second, harsh environmental conditions made construction operations significantly more difficult. In places like Qatar, air temperatures reaching 120 degrees Fahrenheit limited construction crew working time to thirty minutes per session. Extreme daytime temperatures at other locations forced crews to work predominately at night during cooler hours. Sand storms with forty mile per hour gusts further complicated construction operations. Third, the non-availability of contractor support limited construction productivity. Substandard materials, water shortages, and language barriers all had to be overcome. One site at a classified location had only one local contractor with one dump truck (Grier, 2003:3). Finally, the threat of enemy attack made construction operations particularly dangerous. Since the environment at Bagram Air Base was considered too dangerous to conduct daytime repair work, RED HORSE personnel used night vision goggles while operating heavy equipment and repaired the runway and ramp at night (Grier, 2003:2). This was an Air Force first.

1.2 Research Problem

Innovative construction methods exist which can help RED HORSE units overcome the many challenges they face while supporting Air Force contingency missions. Lighter weight construction materials like fabric frame tents or plastic wall sections and construction methods that require less heavy equipment support provide transport advantages over heavier traditional construction materials such as concrete block or wood. Also, simplified pre-fabricated construction methods increase the speed of construction for faster project completion. Easier, faster construction which involves less heavy equipment operation provides safety benefits, especially while operating at night or within hostile environments. Faster construction methods can also be a force multiplier, since manpower and equipment resources finished on one project can be redirected to accomplish secondary priorities. Finally, pre-fabricated, ready-to-build methods can reduce RED HORSE dependence on local contractor support. Since local contractor support can be extremely limited at bare bases, transportability of construction materials and equipment becomes even more critical to project success.

RED HORSE Squadrons already employ a variety of construction methods to meet Air Force contingency mission requirements. These methods range from traditional construction methods using materials such as concrete block and wood to modern, innovative construction methods such as K-Spans, fabric covered frame tents, and pre-fabricated metal buildings. All of these methods have both positive and negative aspects to their design, construction, and performance characteristics and ultimately their ability to meet specific mission requirements.

Deciding which construction method to use is a complex problem because of competing objectives and many alternatives. RED HORSE engineers currently employ an alternatives-driven approach to choosing which construction method to employ for a given contingency. An alternatives-driven methodology limits their decision to known alternatives and may not fully account for every objective they desire to fulfill. Implementing a multiple-objectives methodology could improve their decision process.

1.3 Research Objective

In order to evaluate unlimited construction method alternatives and select the one which best achieves their contingency objectives, RED HORSE should employ a multiple-objectives decision analysis methodology. The objective of this research effort is to develop a multiple-objectives value focused thinking (VFT) decision analysis model based upon a hierarchy of construction method objectives. This VFT model will provide RED HORSE with a reliable, repeatable, and defendable decision tool for evaluating construction method alternatives.

1.4 Research Questions

The ultimate question to be addressed by this research will be: Can a value focused thinking decision analysis methodology help RED HORSE units choose the best construction method alternative to meet their objectives during a deployed contingency? To create the associated VFT model to determine the optimal construction method for a deployed contingency, the decision-maker will be asked to help answer the following questions: What does the decision-maker value in selecting a contingency construction method, and how can these values be measured? Last, the VFT model creation and alternative evaluation results will answer the question: Can an alternative's performance of those values be appropriately quantified and measured to aid alternative selection?

1.5 Research Approach and Scope

RED HORSE engineers typically use an alternatives-driven approach to choosing a suitable construction method for a given contingency, and this decision methodology limits their options to available and familiar alternatives. More importantly, an alternatives-driven decision may not fully account for every objective they desire to fulfill. Therefore, a value focused thinking (VFT) decision model which takes a multiple-objectives approach to evaluating unlimited alternatives will be developed. Using a VFT model will provide the decision-maker greater insight into their complex decision.

Research using VFT as a methodology is an iterative process of collecting and discussing data with the decision-maker. For this research, the VFT model will be developed with the assistance of personnel from the 820th RED HORSE Squadron (RHS), with the 820th RHS Chief of Design acting as the proxy decision-maker. However, the model is intended to be generic enough to be applicable to all RED HORSE units. The VFT model will be created from the top-down, so that the decision-maker's inputs regarding the fundamental objective, values, and measures can be fully captured. Ultimately, various alternative construction methods will be generated and evaluated with the model. The decision-maker will then be able to determine which construction method best meets the fundamental objective.

The scope of this research will be limited to the evaluation of vertical construction methods for use in a deployed contingency only. Horizontal construction methods for runway and road pavements, as well as vertical construction methods available only for state-side implementation, will not be included. The purpose of this research is to determine the optimal construction method(s) for future vertical building projects in an overseas contingency environment.

2. Literature Review

This chapter reviews the literature relevant to this research. After providing a brief history of Rapid Engineering Deployable, Heavy Operational Repair Squadron, Engineering (RED HORSE) units, it discusses two previous comparative analysis studies of construction methods conducted by the Army. These studies investigated and compared the advantages and disadvantages of various construction techniques and materials; they also offered recommendations regarding the potential for future implementation of innovative construction methods. Particularly relevant to this research, the chapter then provides a brief description of several construction methods currently being used by RED HORSE units, as well as some additional methods not currently being used. Finally, an in-depth discussion of the value focused thinking (VFT) decision analysis method used in the research is provided.

2.1 RED HORSE History

According to Dr. Hartzer, the Air Force Civil Engineering Support Agency Historian, RED HORSE was conceived in May 1965 during the Vietnam War in response to then Secretary of Defense McNamara's request for Air Force construction teams to construct expeditionary airfields in combat areas. Major General Curtin, Air Force Director of Civil Engineering, set out the objective to provide "mobile civil engineering units, organic to the Air Force, that are manned, trained, and equipped to perform heavy repairs and upgrade airfields and facilities and to support weapon systems deployed to a theater of operations" (Hartzer, 2004:1). By September 1965, Tactical Air Command began preparing the first two Rapid Engineer Deployable Heavy

Operational Repair Squadron, Engineer (RED HORSE) units, the 554th and 555th, for deployment to Southeast Asia.

Initial training took place at Cannon AFB, New Mexico, in late 1965. Each unit consisted of 400 men, was self-contained, mobile, and capable of providing a variety of skills and construction equipment for supporting Air Force combat units in a theater of operations (Hartzer, 2004:1). In February 1966, the 554th deployed to Phan Rang Air Base and began work on runway repair, and the 555th deployed to Cam Ranh Bay and began work on construction projects. Within a year, "a total of six RED HORSE units had been organized and deployed to Southeast Asia" (Hartzer, 2004:2).

During the next four decades, RED HORSE units proved their indispensable combat construction skills and unique mobile capabilities from the jungles of Vietnam to the deserts of Iraq. RED HORSE performed contingency construction missions in Southeast Asia from 1966 to the mid-1970's, in Korea from 1968 to present, in Central America and the Caribbean from the early 1970's to present, in Africa in 1993, in the Balkans in the 1990's, and in Southwest Asia during Operations DESERT SHIELD and DESERT STORM in the early 1990's. RED HORSE continues to support current Operations ENDURING FREEDOM and IRAQI FREEDOM at deployed locations throughout Southwest Asia (Hartzer, 2004).

The history of the 820th RHS, indicative of the proud histories of every RED HORSE unit, dates back to the unit's origin as the 820th Installations Squadron at Plattsburgh AFB, New York, in June 1956 (Hartzer, 2004). After a brief period of inactivation, the unit was reactivated in 1966 and redesignated as the 820th Civil Engineering Squadron (CES), Heavy Repair. In July 1966, the unit began training for deployment to Tuy Hoa Air Base, Vietnam. The 820th CES deployed to Tuy Hoa in October and was eventually assigned to the 1st Civil Engineering Group

(Hartzer, 2004). At Tuy Hoa Air Base, the 820th CES completed nearly fifty percent of all construction including 170 aircraft parking revetments, 120,000 square feet of wooden buildings, and 175,000 square yards of AM-2 aircraft platform mat (Hartzer, 2004). The unit moved to Da Nang Air Base, Vietnam, in February 1969, where it was reassigned to the Seventh Air Force. On 15 April 1970, the 820th CES returned to the United States to its new home station at Nellis Air Force Base, Nevada (Hartzer, 2004).

First assigned to the Tactical Air Command and now to Air Combat Command, the 820th CES was redesignated the 820th RED HORSE Civil Engineering Squadron on 10 March 1989 (Hartzer, 2004). In 1990, the 820th deployed a RED HORSE contingent to join with the 823rd and 7319th RED HORSE units in support of the Gulf War. The composite RED HORSE unit completed over twenty-five construction projects valued at nearly $15 million at twelve geographically separated locations throughout the Arabian Peninsula (Hartzer, 2004:5). In just weeks, RED HORSE teams turned the bare base at Al Kharj into a fully operational air base capable of supporting five fighter squadrons. Projects included aircraft parking platforms, seventeen K-Span facilities, new road networks, and a munitions storage area. After returning to Nellis, the 820th was redesignated the 820th RED HORSE Squadron (RHS) on 1 March 1994 (Hartzer, 2004).

The 820th RHS again joined members of the 823rd in 1999 to deploy to Albania supporting Operation ALLIED FORCE. Extremely muddy conditions at Tirana, Albania, did not prevent the RED HORSE teams from constructing a new 18-inch thick concrete C-17 aircraft ramp and 1000-foot long taxiway, improving the USAF tent city facilities, and installing various roads and support infrastructure (Hartzer, 2004). Beginning in 2002 and continuing to the present, the 820th RHS deployed multiple times to Southwest Asia in support of Operations

ENDURING FREEDOM and IRAQI FREEDOM. At Al Dhafra Air Base, United Arab Emirates, the 820th RHS undertook and completed construction of a one million square-foot aircraft parking ramp and associated infrastructure (Hartzer, 2004). Assigned to the 1st Expeditionary RED HORSE Group, the 820th RHS teams helped construct hundreds of tents and other support facilities throughout Afghanistan and Iraq and the surrounding area of operations. For over four decades, the 820th RED HORSE Squadron has provided agile combat support to USAF missions from the jungles of Vietnam to the deserts of Iraq (Hartzer, 2004).

2.2 Previous Studies of Construction Methods

A review of the literature found two reported studies that investigated alternative building technologies for military application (Kao and Cook, 1977; and Napier, Holcomb, Kapolnek, and Rivas,1988). These studies performed a comparative analysis on innovative contingency construction techniques and made recommendations regarding Army implementation of these methods on future projects. This review served two purposes: it provides insight into the methods typically used to compare various construction techniques and suggests performance characteristics which might be considered by RED HORSE engineers in their decision process. Both studies are briefly discussed below.

2.2.1 Kao and Cook (1977) Study

The study by Kao and Cook (1977) was conducted after Army leadership recognized the need for new and improved construction methods for future tactical construction scenarios. This study documented the findings resulting from fabricating and erecting two prototype building systems: a fiberglass-reinforced paperboard building and a pipe-frame building. These building systems were constructed by Army engineers and performance characteristics were observed over a one-year period; cost, constructability, weatherability, and structural strength were all observed and reported.

The fiberglass-reinforced paperboard building system showed advantages in shipping and erection ease but experienced problems with high humidity and intense heat. The paperboard building materials require protection from moisture and heat during shipping and prior to erection which could cause difficulty in austere environments. The paperboard building was also determined to be non-relocatable. The cost of this system was $7.95 per square foot (Kao and Cook, 1977:36).

The pipe-frame building method was recommended for further research and potential use in tactical theater operations. Advantages of the pipe-frame system included easy erection, with relatively unskilled labor and no special tools or equipment requirements. The pipe-frame building was considered relocatable, expandable, and lightweight compared to traditional buildings (Kao and Cook, 1977:47). The cost of this system was $7.10 per square foot (Kao and Cook, 1977:36).

2.2.2 Napier et al. (1988) Study

The Napier et al. (1988) study examined a third alternative construction technique: architectural fabric structure technology. Three building contracts were awarded to fabric structure contractors at sites in Texas, South Korea, and Germany. The projects were monitored throughout the construction process; cost, schedule, and quality were reported. The main advantage of these structures was the ability to provide superior interior clear space at low additional cost (Napier et al., 1988:79). The Army recommended further study and implementation of this type of construction method. The fabric structure buildings proved to be successful alternatives to traditional building systems in both constructability and cost-competitiveness.

2.3 Additional Innovative Construction Methods

Besides the construction methods discussed above, several commercially available innovative construction methods exist which might be beneficial to future RED HORSE contingency applications. RED HORSE engineers have experience working with pre-engineered steel structures, reinforced concrete buildings, and fabric tent structures. Therefore, this section introduces several construction methods for which the RED HORSE units have the expertise to be bale to use on future deployed contingency projects. The potential advantages and disadvantages of these methods are also discussed.

2.3.1 K-Span

The K-Span building system is an innovative vertical construction technique employed extensively by RED HORSE and commercial contractors at various sites around the world during the past decade. K-Spans consist of roll-formed arched steel structures that weld together in large sections to produce a self-supporting building with no internal structure. Figure 2.1 shows a typical K-Span building being erected.

Figure 2.1. K-Span Construction (Spanco Building Systems, 2004:3)

This building system is particularly beneficial for Air Force projects like small aircraft hangars or large maintenance shops which require large internal clearance space. The on-site steel shaping machinery also allows construction crews to tailor the building to their specific requirements. Once erected, K-Span buildings provide a long service life and require minimal maintenance (Spanco Building Systems, 2004). The 554th RED HORSE Squadron built a 90 feet by 176 feet super K-Span at Kimhae Air Base, South Korea, in mid-2000 in less than 95 days for a construction cost of $450,000 (Global Security, 2003). The building serves a dual purpose of storing war reserve materiel during peacetime and troop housing during war. Speed of construction and cost per square foot for a facility of this size are both advantages of K-Spans.

Contingency construction limitations with K-Spans include the need for heavy support equipment like cranes or large forklifts for building erection. This can make airlifting this building method costly and perhaps prohibitive. Also, the thin sheet metal type exterior of the finished facility does not provide adequate force protection for troops in a hostile environment.

2.3.2 Pre-Engineered Building

A second method using steel construction which can be utilized for contingency construction projects is the pre-engineered building (PEB). A PEB is defined as a "metal building system that consists of a fully integrated, computer-designed, factory fabricated structural, roof, and exterior wall system" (Hanmaek, 2005). The PEB is widely used throughout the United States and around the world for commercial and industrial applications. Figure 2.2 is a cross-section of a typical rigid frame PEB.

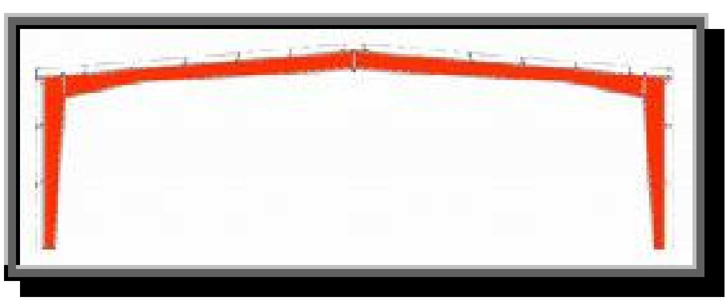


Figure 2.2. Typical Rigid Frame Pre-Engineered Building (Rigid Building Systems, 2005)

A PEB can be designed with bay spacings from 20-30 feet, spans from 20-150 feet, and eave heights from 10-25 feet. Column-free unobstructed working space of this size makes this type of construction ideal for small aircraft hangars or large warehouses (Rigid Building Systems, 2005:3). Like the K-Span, the PEB offers the advantage of providing a large facility with expansive interior clear space. PEBs also provide faster construction time compared to traditional structural steel construction (Rigid Building Systems, 2005:1). According to one manufacturer, Rigid Building Systems, design time for a PEB structure takes approximately three weeks, and materials can be delivered to the construction site within two months (Rigid Building Systems, 2005:3). The cost of a PEB is 40% lower than a similar sized conventional steel building.

One disadvantage in using a PEB for a deployed contingency is the fact that the steel components weigh more and take up more space during transportation. Also like the K-Span, construction requires the support of heavy equipment pieces like cranes and fork lifts. The 554th RED HORSE Squadron built a second facility at Kimhae Air Base in 2000, a 50 feet by 100 feet PEB for $457,000 in 120 days (Global Security, 2003).

2.3.3 Tilt-Up

Another innovative vertical construction method being used in the commercial sector is concrete tilt-wall. Concrete tilt-wall construction or tilt-up has recently been employed extensively on light commercial buildings and residential building projects. Figure 2.3 shows a custom precast concrete tilt-wall section being erected.

Figure 2.3. Tilt-Wall Building Section Erection (Lurz, 1999:106)

Tilt-wall advantages include reduced cost compared to wood frame building, due to the price volatility of lumber. World-wide, concrete has also become the material of choice for many builders, since concrete offers advantages over traditional materials in weatherability and durability. Royal Wall is one manufacturer of tilt-wall construction materials and cites tilt-wall material strength and speed of construction as key advantages (Lurz, 1999:105-108). Other precast concrete tilt-wall advantages include easier quality control, custom capability per project requirements, and faster transition between wall erection and building completion (Power, 1999:132). Unlike the relatively thin walled pre-fabricated steel structures discussed previously, tilt-wall buildings offer significantly increased force protection benefits since the walls are composed of reinforced concrete. Additionally, tilt-wall construction can cost approximately half as much as traditional concrete masonry unit (CMU) construction.

Tilt-wall erection requires the use of large heavy equipment pieces namely cranes. This presents a distinct disadvantage for using this type of construction method in remote locations where contractor support is limited. Tilt-wall is also more labor intensive than other contingency construction methods, and the delivery time for receiving construction materials at the project sire might be longer.

2.3.4 Plastic Finished Concrete Forms

A fourth innovative construction technique, the erection of plastic finished formwork which is filled with reinforced concrete, could be a new way of performing vertical construction in deployed contingency environments. Royal Building Systems (RBS) is a derivative of Royal Building Technologies, a Canadian plastics company that supports the construction industry world-wide with innovative plastic building solutions. Specifically, RBS is a patented polymer-based stay-in-place formwork for concrete walls and structures. The extruded components slide and interconnect to create a concrete formwork which then is filled with reinforcement bars and concrete. Figure 2.4 is an illustration of a typical Royal Building System wall section. The end result is a reinforced concrete building with a plastic interior and exterior surface (Royal Building Systems, 2001).

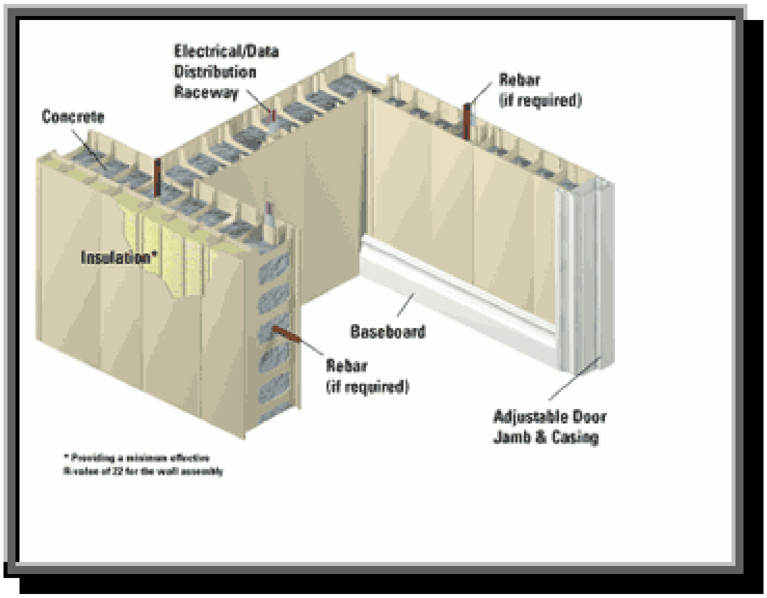


Figure 2.4. Typical Royal Building System Wall Sections (Royal Building Systems)

RBS wall systems can be erected much faster than traditional CMU methods. The structural frame of a 1,200 square foot single-story building can be completed in only 14 days (Royal Building Systems, 2001) as compared to a CMU building of the same size which might take six weeks. The RBS wall system has already been used in over 40 countries and has withstood severe loading conditions such as hurricanes and earthquakes. The combined strength of concrete and durability of plastic have enabled RBS buildings in Russia, Colombia, and the Caribbean to withstand otherwise debilitating earthquakes and hurricanes (Morrissey, 1999). Like tilt-wall, RBS offers significant force protection advantages over soft walled facilities.

RBS structures provide several advantages over traditional construction methods that might be key to Air Force contingency applications. The plastic forms can be extruded in various sizes to add flexibility to RED HORSE design needs. The plastic wall sections are lightweight, so they could easily be transported by military aircraft around the world. In storage or on the building plastic resists decay and will not deteriorate as quickly in harsh environments as traditional construction materials. At location, the plastic wall sections can be erected quickly by crews with limited specialized tools and heavy equipment support. Finally, once erected, the plastic forms can be filled with locally procured concrete to expedite construction timelines and speed project completion (Royal Building Systems, 2001).

Potential disadvantages of using RBS for contingency applications might be that RBS facilities are not modular. Should on-site facility expansion be required, design modifications would be necessary before additional sections could be added to an existing facility. Also, RBS construction requires concrete pumping trucks to place the concrete into the plastic formwork. Such heavy equipment support could be limited at deployed remote locations.

2.3.5 Alaska Small Shelter System

The predominant vertical contingency construction method currently employed by USAF engineers is the erection of fabric covered frame tents. The Alaska Small Shelter System (AKSSS) and the California Medium Shelter System (CMSS) are the latest of this structure type to be introduced to the military. The AKSSS is a self-contained and portable, state-of-the-art personnel shelter that comes prepackaged with interior electrical and lighting, environmental control unit, and shipping container. Recently, Alaska Structures was awarded a multi-year contract to replace the USAF's twenty-year old Tent Extendable Modular Personnel tents (TEMPER tents) (Alaska Structures, 2005). Figure 2.5 is a picture of an erected AKSSS provided by Headquarters Air Force Civil Engineer Support Agency (HQ AFCESA).

Figure 2.5. Typical Alaska Small Shelter (HQ AFCESA, 2001)

Alaskan Small Shelters have many advantages for billeting and office type contingency applications. They are lightweight, easily transported, and modular. They can also be erected quickly and require no heavy equipment support. California Shelters have the same benefits of transportability and fast erection, but they do require some heavy equipment support. A major disadvantage of Alaskan and California Shelters is that these soft-walled fabric facilities provide no force protection against enemy attack.

2.3.6 TEMPER Tent

Like the AKSSS, the TEMPER Tent (Tent Extendable Modular Personnel Tent) is a modular frame tent structure where an aluminum frame supports a synthetic material fabric covering. TEMPER tents are modular, and each module is 8 feet wide by 20 feet long and can be joined width-to-width to make any length facility. The most common configuration is the 20 feet by 32 feet billeting tent configuration which can house up to twelve troops. Figure 2.6 shows an erected TEMPER tent.

Figure 2.6. Typical TEMPER Tent (AFH 10-222 Vol. 6, 1999)

This 640 square feet facility weighs approximately 1200 pounds, and it can be easily folded, packed, and airlifted (Air Force Handbook 10-222 Vol. 6, 1999:7). Like the AKSSS, the main advantage of TEMPER tents is that these types of structures can be erected in hours by RED HORSE engineers versus weeks or months using alternative methods of construction. These assets are lightweight which allows for easier transportability and greater mobility. These systems are also modular, so they can be site-adapted to accommodate larger billeting missions or storage requirements.

Disadvantages of using soft-walled facilities include the temporary nature of the materials and the lack of force protection these facilities provide. In high threat areas where small arms fire or fused munitions are a primary concern, AKSSS, California Shelters, and TEMPER tents provide extremely limited survivability (AFH 10-222 Vol. 6, 1999).

2.4 Decision Analysis

RED HORSE engineers must determine which expedient construction method best meets the requirements presented to them in any given deployed contingency situation. Choosing the most appropriate construction method is a complex problem, as site conditions at any potential bare base environment may pose different challenges. Additionally, RED HORSE engineers must meet the needs of the warfighters who will ultimately occupy the constructed facilities; these needs vary from mission to mission and frequently change during the design process or deployment. All of these factors impact which method of construction will achieve the greatest success.

Since RED HORSE engineers are faced with multiple objectives and multiple alternatives, their decision process is ideal for multiple-objectives decision analysis. Therefore, subsequent sections of the literature review highlight the value focused thinking (VFT) decision analysis process to be used to evaluate deployed vertical construction method alternatives for any given contingency. In the next section, the VFT terminology is defined and the ten-step VFT process is discussed in depth.

2.5 Value Focused Thinking

Keeney (1992:3) explains that any decision should focus on achieving the decision-maker's objective(s). "Values are what we care about. As such, values should be the driving force for our decision-making" (Keeney, 1992:3). Instead of focusing solely on the alternatives available, a decision-maker should first identify the objectives of the decision to be made and evaluate all possible alternatives according to how well they achieve desired values. If the decision-maker performs a decision analysis based on values versus simply choosing between alternatives, the decision-maker stands a greater chance of determining the best alternative to meet the strategic objective(s). "Value Focused Thinking (VFT) essentially consists of two activities: first deciding what you want and then figuring out how to get it" (Keeney 1992:4). Some of the commonly used VFT terminologies are defined in Table 2.1 (Jurk, 2002). The remaining portion of this literature review compares the VFT methodology to the more commonly practiced Alternative Focused Thinking method, and then explains the 10-step VFT process (Shoviak, 2001) implemented in this thesis.

Table 2.1. Value-Focused Thinking Terminology and Definitions (Jurk, 2002:27)

Fundamental Objective	"…an essential reason for interest in the decision situation" (Keeney, 1992:34). Also known as the "ends objective," it is the top block in the value hierarchy.
Value	What is important to the decision-maker (Clemen, 1996:19). The values are the decomposition of the fundamental objective. They are the building blocks of the value hierarchy.
Value Hierarchy	A pictorial representation of a value structure (consisting of the fundamental objective, the values, and the measures) (Kirkwood, 1997:12).
Measure	Analogous to the term "metric," it notes the "degree of attainment" of a value (Kirkwood, 1997:12).
Local Weight	The amount of weight a set of lower-tier values or measures contributes to the value directly above it in the hierarchy (Shoviak, 2001:57).
Global Weight	The amount of weight each lower-tier value or measure contributes to the weight of the hierarchy's fundamental objective (Shoviak, 2001:57).
Alternative	"…the means to achieve the…values" (Kenney, 1992:3).
Score	A "specific numerical rating for a particular alternative with respect to a specified measure" (Kirkwood, 1997:12).
Single Dimensional Value Function (SDVF)	A specific, monotonically increasing or decreasing function for each measure used to convert an alternative's "score" on the x-axis to a "value" on the y-axis.

2.5.1 Alternative Focused Versus Value Focused Thinking

Alternative Focused Thinking (AFT) emphasizes choosing between known alternatives or the alternatives currently available to the decision-maker. Value Focused Thinking (VFT), on the other hand, emphasizes the values or objectives which the decision-maker hopes to achieve, and alternatives provide the means to achieve those values. Most decisions are approached through an AFT methodology, wherein the choice is limited to the alternatives at hand. Keeney (1994:33) describes this approach as reactive, because the best outcome the decision-maker can hope for is to make a less bad decision. The Army studies presented earlier in this chapter are examples of comparative analyses that employ an AFT methodology, and most construction method decisions are similarly conducted. If a decision-maker is faced with a clear choice between two or more known alternatives, and the desired outcome is already apparent with no hidden objectives, then a straight forward and perhaps faster AFT decision is appropriate.

However, in cases where a decision-maker faces a complex decision with potentially hidden objectives and multiple, perhaps even unknown alternatives, a VFT approach can lead to a better decision outcome (Keeney, 1992:22). Keeney describes the VFT approach as proactive, since the decision-maker structures the decision process around the desired values and objectives (Keeney, 1994:33). Focusing on the objectives and values of the decision has the benefits indicated in Figure 2.7.

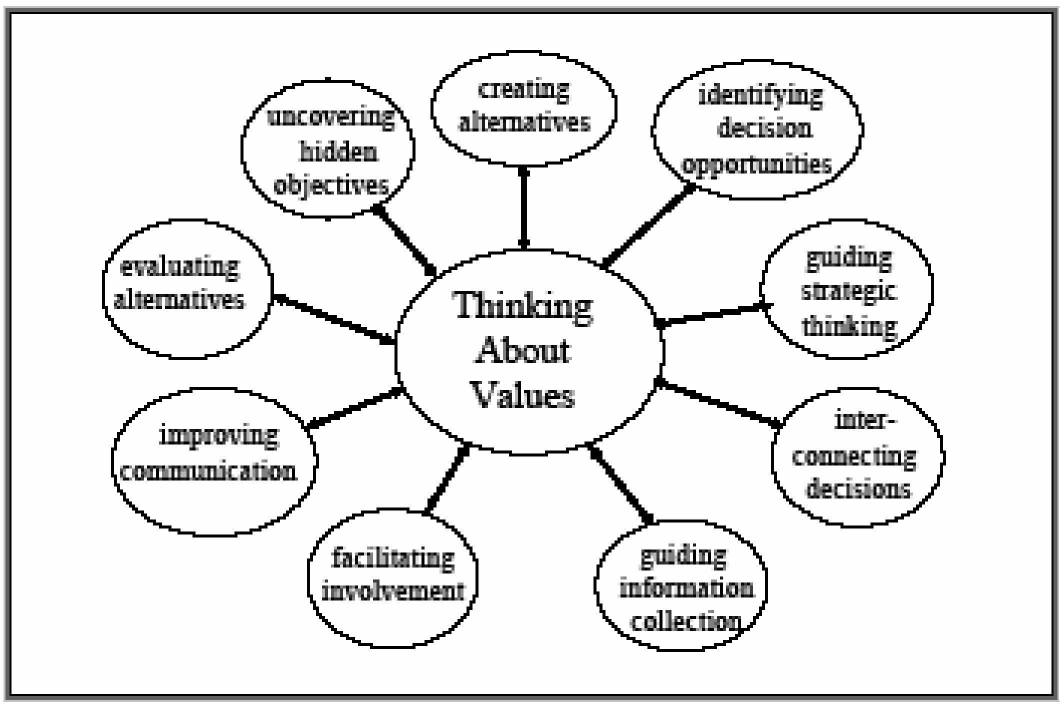


Figure 2.7. Overview of Value Focused Thinking Benefits (Keeney, 1992:24)

A VFT approach to complex decisions facilitates communication between multiple stakeholders, guides decision strategy by highlighting what is important, and helps the decision-maker identify and evaluate potential alternatives (Kirkwood, 1997:22-23). VFT allows the alternatives to be evaluated against how well they attain the desired values, and further, ensures the methodology for quantifying value judgments is logical and sound (Keeney 1992:26). Finally, a VFT approach can uncover hidden objectives and identify decision opportunities. New objectives and opportunities can lead to even greater decision results than were initially apparent at the start of the decision process (Keeney, 1992:24-27). According to Keeney (1994:33), "the greatest benefits of value focused thinking are being able to generate better alternatives for any decision problem and being able to identify decision situations that are more appealing than the decision problems that confront you."

2.5.2 Ten-Step Process for Value Focused Thinking

Implementing VFT as a decision analysis methodology aids the decision-maker in structuring and quantifying a value model to better understand the values relevant to a complex decision (Keeney, 1992:130). The framework for developing an insightful value model involves an iterative approach in which the decision-maker provides qualitative and quantitative inputs to the model builder. These inputs become the basis upon which an optimal decision can later be reached. In 2001, Shoviak compiled the VFT decision analysis methodology from works by Keeney (1992), Kirkwood (1997), and Kloeber (2000) into a ten-step process shown in Figure 2.8 (Shoviak, 2001:47). Each of these steps is described in more detail below.

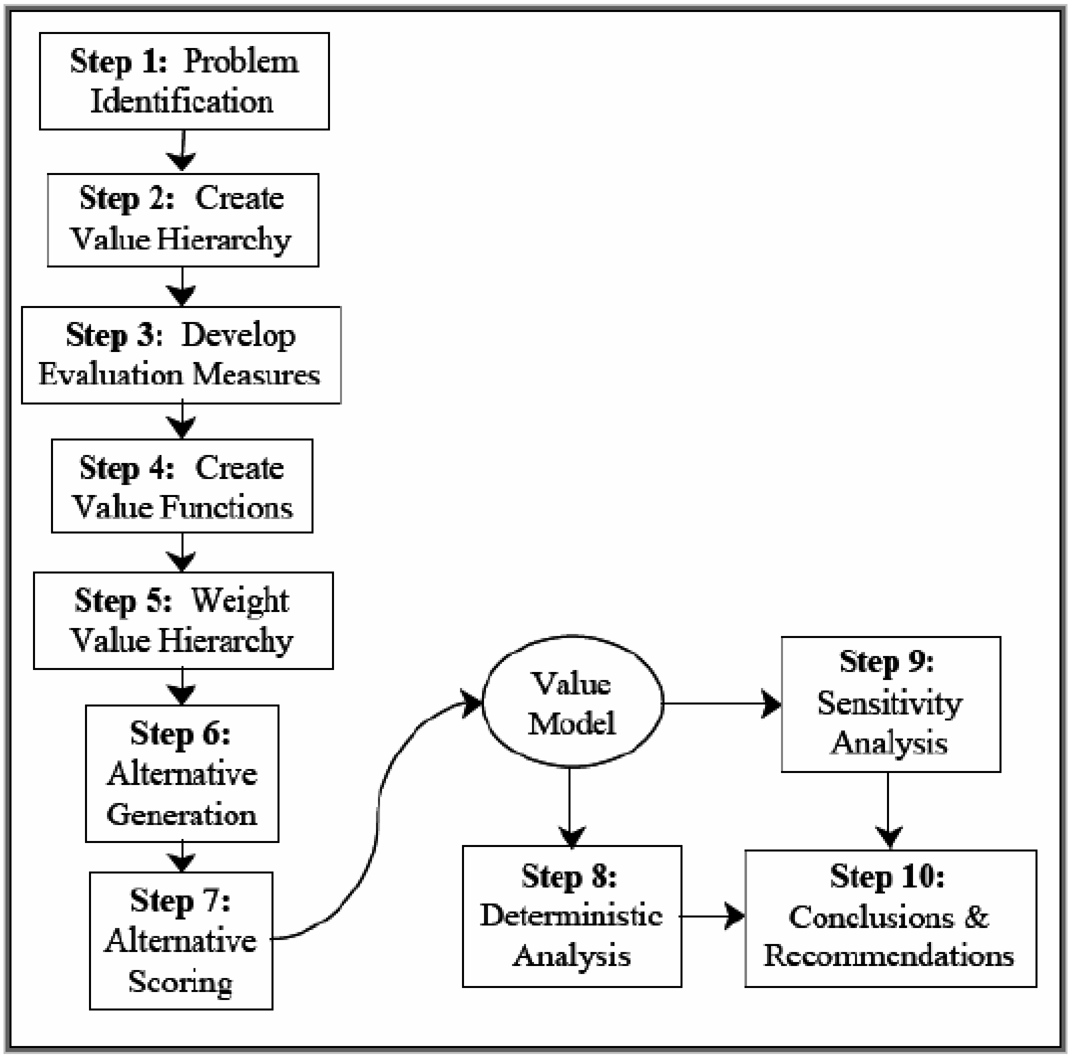


Figure 2.8. Value Focused Thinking Ten-Step Process (Shoviak, 2001:63)

2.5.2.1 Problem Identification

The first step in the VFT process is identifying and articulating the problem. Otherwise known as the fundamental objective, this is the reason for the decision analysis to be conducted. The fundamental objective becomes the top tier in the value hierarchy. This is illustrated in Figure 2.9 an example of a generic value hierarchy.

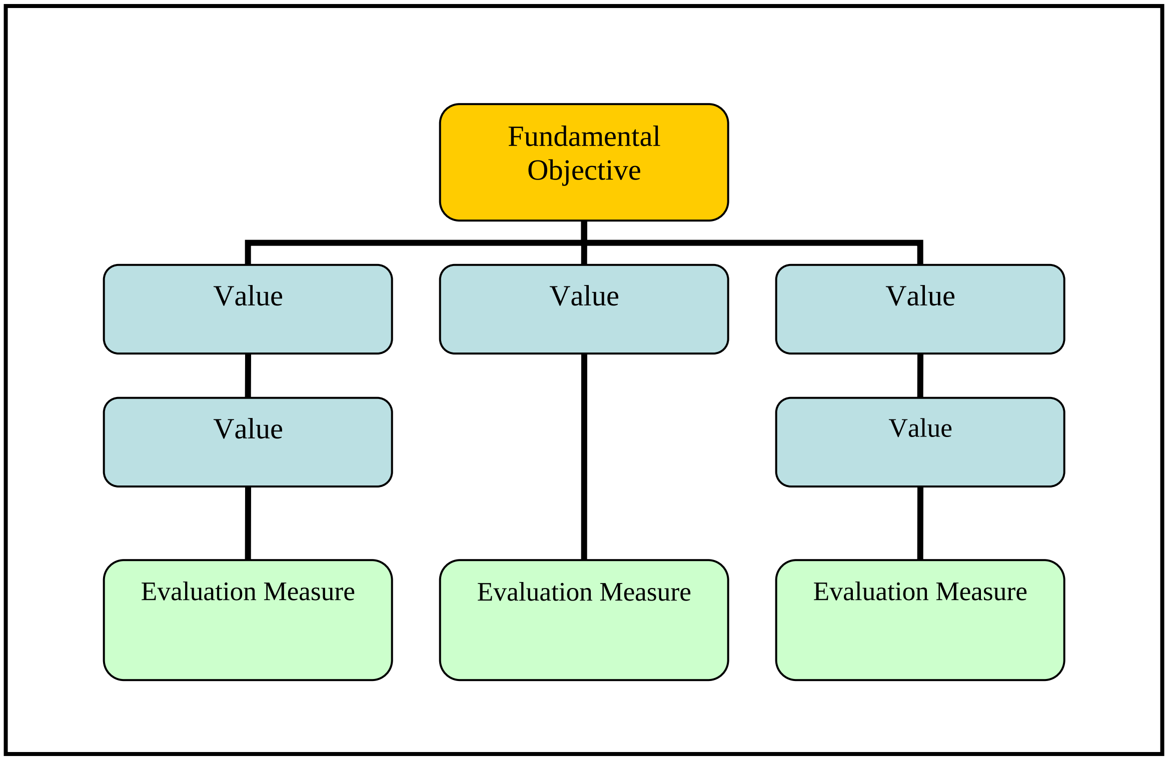


Figure 2.9. Generic Value Hierarchy

2.5.2.2 Create Value Hierarchy

The fundamental objective is further refined into successively more specific means objectives or values. These values represent the decision-maker's "preferred direction of movement with respect to the evaluation consideration" (Kirkwood, 1997:12). The values are placed in the value hierarchy in echelon below the fundamental objective. Thus, the value hierarchy serves as the backbone of the VFT decision analysis framework. This tree-like diagram incorporates the decision-maker's objectives, values, and evaluation measures into a tiered value hierarchy which provides structure and insight to the decision process (Kirkwood, 1997:12). Values located the same distance from the top of the hierarchy constitute a single layer or tier (Kirkwood, 1997:13).

Kirkwood (1997:16-19) explains that value hierarchies should attempt to attain five desirable properties: completeness, nonredundancy, decomposability, operability, and small size. A complete value hierarchy must include every value necessary to fully evaluate the fundamental objective, and the evaluation measures must "adequately measure the degree of attainment of their associated objectives" (Kirkwood, 1997:16). The final group of values and measures represented in the hierarchy must be collectively exhaustive. A nonredundant value hierarchy must be mutually exclusive, so that "no two evaluation considerations in the same [tier] of the hierarchy should overlap" (Kirkwood, 1997:16-17). Nonredundancy ensures that the same value or measure will not be "double counted" somewhere else within the model. A decomposable or independent value hierarchy ensures that the score an alternative receives for one evaluation measure does not immediately influence the same alternative's score in another measure (Jurk, 2002:32). An operable value hierarchy should be clearly understood by the people who need to use it and also easily communicated to others interested in the decision process (Kirkwood, 1997:18). Last, a small sized value hierarchy further facilitates communication between interested parties and "requires fewer resources to estimate the performance of alternatives with respect to the various evaluation measures" (Kirkwood, 1997:18).

2.5.2.3 Develop Evaluation Measures

Evaluation measures are the quantifiable performance metrics for the values directly above them in the value hierarchy. An evaluation measure provides the "scale for the degree of attainment of an objective" (Kirkwood, 1997:12). Also referred to as the measure of effectiveness or performance measure of an objective, they are represented at the bottom of the value hierarchy.

There are four types of measure scales: natural-direct, natural-proxy, constructed-direct, and constructed-proxy. Natural scales are those measures that are commonly used and interpreted by everyone, like using inches or feet to measure distance. Constructed scales are those developed to measure the level of attainment for a specific decision objective (Kirkwood, 1997:24). Constructed scales can be categorical like full-time, on-demand, or none for the evaluation of four-wheel drive (Jurk, 2002:39). Natural and constructed scales are also either direct or proxy. Direct scales directly measure the performance of an alternative in meeting an objective, whereas proxy scales measure the degree of performance of an associated objective (Kirkwood, 1997:24). Miles per gallon for the evaluation of a vehicle's MPG is an example of a direct scale, whereas the number of stars given to a vehicle for its crash test rating is an example of a proxy scale (Jurk, 2002:39). Natural-direct measures are preferred, since they are already established and most easily understood. Conversely, constructed-proxy measures are least preferred and should only be created when natural or direct measures do not exist for that particular objective evaluation. Additional examples of the four possible measure scale combinations are shown in Table 2.2.

Table 2.2. Examples of Evaluation Measure Scales (Weir, 2004)

	Natural	Constructed
Direct	Net Present Value Time to Accomplish Cost to Accomplish	Olympic Diving Scoring Weather Prediction Categories R&D Project Categories
Proxy	Gross National Product (Economic Growth) Number of Subsystems (System Reliability)	Performance Evaluation Categories (Promotion Potential) Student Grades (Student Learning)

Ultimately, evaluation measures should meet Keeney's three desirable properties: measurability, operationality, and understandability (Keeney, 1992:112). Measurability refers to the more precise definition of the associated value within the measurement "than that provided by the [value] alone" (Keeney, 1992:113). The measure must quantify the value intended by the decision-maker and nothing more. Operationality implies that a measure will "describe the possible consequences with respect to the associated [value] and provide a sound basis for value judgments about the desirability of the various degrees to which the [value] might be achieved" (Keeney, 1992:114). Finally, understandability means there is "no loss of information when one person assigns a [measure] level to describe a consequence and another person interprets that [measure] level" (Keeney, 1992:116). Evaluation measures that contain these three desirable properties will clarify the respective values and facilitate VFT (Keeney, 1992:112).

2.5.2.4 Create Value Functions

Step four in the VFT process is creating the value functions, also called single dimensional value functions (SDVF). Each evaluation measure developed in Step 3 of the VFT process has specific units, and these units may be different from each other. Therefore, the measures must be converted into common scores with units of "value" between 0 and 1 (Jurk, 2002:41-42). Using this convention, "the least preferred score being considered for a particular evaluation measure will have a single dimensional value of zero, and the most preferred score will have a single dimensional value of one" (Kirkwood, 1997:61). The SDVFs are graphical conversion charts developed by the model builder after soliciting decision-maker input and can be either discrete or continuous. Examples of increasing discrete and continuous SDVFs are shown in Figure 2.10 (Weir, 2004). SDVFs can also be decreasing; linear or exponential; and concave, convex, or S-shaped.

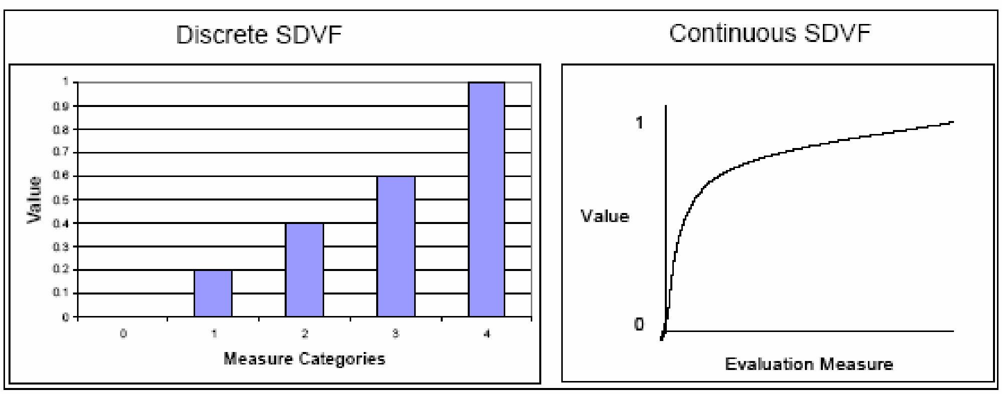


Figure 2.10. Examples of Discrete and Continuous Value Functions (Weir, 2004)

2.5.2.5 Weight Value Hierarchy

A useful value model not only includes all of the values desired by the decision-maker, it also identifies the importance of each value relative to the other values. Since it is unlikely that every value is equally important to the overall decision objective, the model builder solicits the decision-maker's expertise to subjectively weight each value and measure within the hierarchy. Two types of weights can be used: local and global (Weir, 2004). Local weights refer to the level of importance each value or measure has within its own tier within the same branch of the hierarchy. "An important property of the hierarchy is that the local weights for each branch and each tier, taken separately, must sum to 1.0" (Jurk, 2002:44). Global weights refer to the overall importance a value or measure has on the fundamental objective or the entire value hierarchy. The global weights for each tier across all branches of the hierarchy must sum to 1.0. By definition, the fundamental objective has a local and global weight equal to 1.0, since it is alone at the top of the value hierarchy. Applying a top-down approach, each value in the next lower tier is assigned a local weight based on its importance to the decision objective relative to the other values in the same tier. This process is continued until every value and measure within the hierarchy has been assigned a local weight. The global weight of each value and measure can then be calculated by simply multiplying its own local weight by the local weights of the values in the branch directly above it to the top of the hierarchy.

After creating the SDVFs and weighting the value hierarchy, value scores for each alternative can now be assessed. The additive value function shown in Figure 2.11 (Mayer, 2003:19-20) combines all the evaluation measures into a single overall value score for each alternative (Kirkwood, 1997:53). The additive value function is the most commonly used function for decision analysis due to its simplicity and effectiveness for performing sensitivity analysis (Kirkwood, 1997:230). Using this function, an alternative's total value score is calculated as the sum of each evaluation measure's individual SDVF score multiplied by its global weight. Theoretically, a perfect alternative would achieve a total value score of 1.0 for the decision objective, meaning that every evaluation measure scored a 1.0 as well. Similarly, an alternative that scores zero on every evaluation measure would receive a zero total value score (Kirkwood, 1997:61).

$$v(x) = \sum_{i=1}^{n} w_i v_i(x_i) \qquad (1)$$

where

$v(x)$ = The value function

$v_i(x_i)$ = The single dimension value function i

w_i = The weight for evaluation measure i

$$\sum_{i=1}^{n} w_i = 1.0 \qquad (2)$$

Figure 2.11. Additive Value Function (Mayer, 2003:19-20)

2.5.2.6 Alternative Generation

Either an outside source or the decision-maker provides a list of alternatives to be evaluated. Keeney explains that often the first alternatives that come to mind are the obvious ones, or ones that are readily available and familiar to the decision-maker (Keeney, 1992:9). This can lead to an unnecessarily narrow range of alternatives. To avoid this, focus should remain on the desired values guiding the decision process, and the decision-maker should try to identify creative alternatives (Keeney, 1992:9). Guided by the value model, the decision-maker might develop alternatives or combinations of alternatives not previously considered.

2.5.2.7 Alternative Scoring

Once a list of potential alternatives has been developed, data must be collected for each to be evaluated by the value model. The evaluation measures already created and built into the model help focus the data collection effort. Typically, the decision-maker has personal knowledge of the alternatives or ready access to the information on the alternatives or can at least contact the necessary subject matter experts to locate the required data. In an ideal situation, a forum of subject matter experts collectively considers each alternative against each evaluation measure. This helps maintain value model clarity and consistency during the alternative scoring process and adds defensibility to the final value score results (Jurk, 2002:53).

2.5.2.8 Deterministic Analysis

Deterministic analysis is step eight in the VFT process (Shoviak, 2001). The value model uses the additive value function, which was previously explained, to calculate the final value score for each alternative. Once scored, the alternatives can be ranked according to how well they achieve the decision objective. Deterministic analysis provides the decision-maker with greater insight as to how well each alternative scored in each of the model's value objectives and evaluation measures. Further, the simplicity of the additive value function encourages easy, detailed sensitivity analysis (Kirkwood, 1997:230).

2.5.2.9 Sensitivity Analysis

The next to last step in the VFT process is sensitivity analysis, which involves analyzing the sensitivity of the alternative rankings to changes in weight values (Shoviak, 2001:61). Sensitivity analysis is post-deterministic analysis that tests the modeling assumptions inherent in the weighting of each value. This is performed by varying the weight of one value in a value tier while keeping the proportion of the remaining value weights in that tier constant. This enables the decision-maker to gain insight into how the variation of a single value's weighting changes the final value score and ranking of the alternatives (Jurk, 2002:54-55). Sensitivity analysis helps the decision-maker better understand the impact of the weighting within the value model and ultimately feel more confident in the final decision.

2.5.2.10 Recommendations and Presentation

Conclusions and recommendations is the final step in the VFT process (Shoviak, 2001). Results of the evaluation and analysis of the value model can now be presented to the decision-maker. The value focused approach to structuring a multiple-objectives decision provides the decision-maker with a reliable and repeatable decision tool for evaluating multiple alternatives against competing objectives. The final value score rankings of the alternatives provide useful insight to the decision-maker in choosing the optimal alternative to achieve the fundamental objective of the decision.

2.6 Summary

Chapter 2 provided historical information on the RED HORSE concept and indicated the variety of deployed contingency construction projects they perform. Two previous Army studies on innovative construction methods were discussed to illustrate the current alternative-based thinking approach to comparing construction methods, and then several additional innovative construction methods were introduced. Finally, the value focused thinking decision analysis approach was introduced, and the ten-step VFT process to be implemented in this research effort was explained in detail. Chapters 3, 4, and 5 provide the methodology, results, and conclusions of using the VFT approach for this research.

3. Methodology

Chapter 3 explains the phased process used in this research effort to develop a Valued Focused Thinking (VFT) decision analysis model to help Rapid Engineering Deployable, Heavy Operational Repair Squadron, Engineer (RED HORSE) units evaluate multiple vertical construction methods for use in a deployed contingency. The methodology used for this research was the ten-step VFT process pioneered by Shoviak (2001) and shown in Figure 3.1.

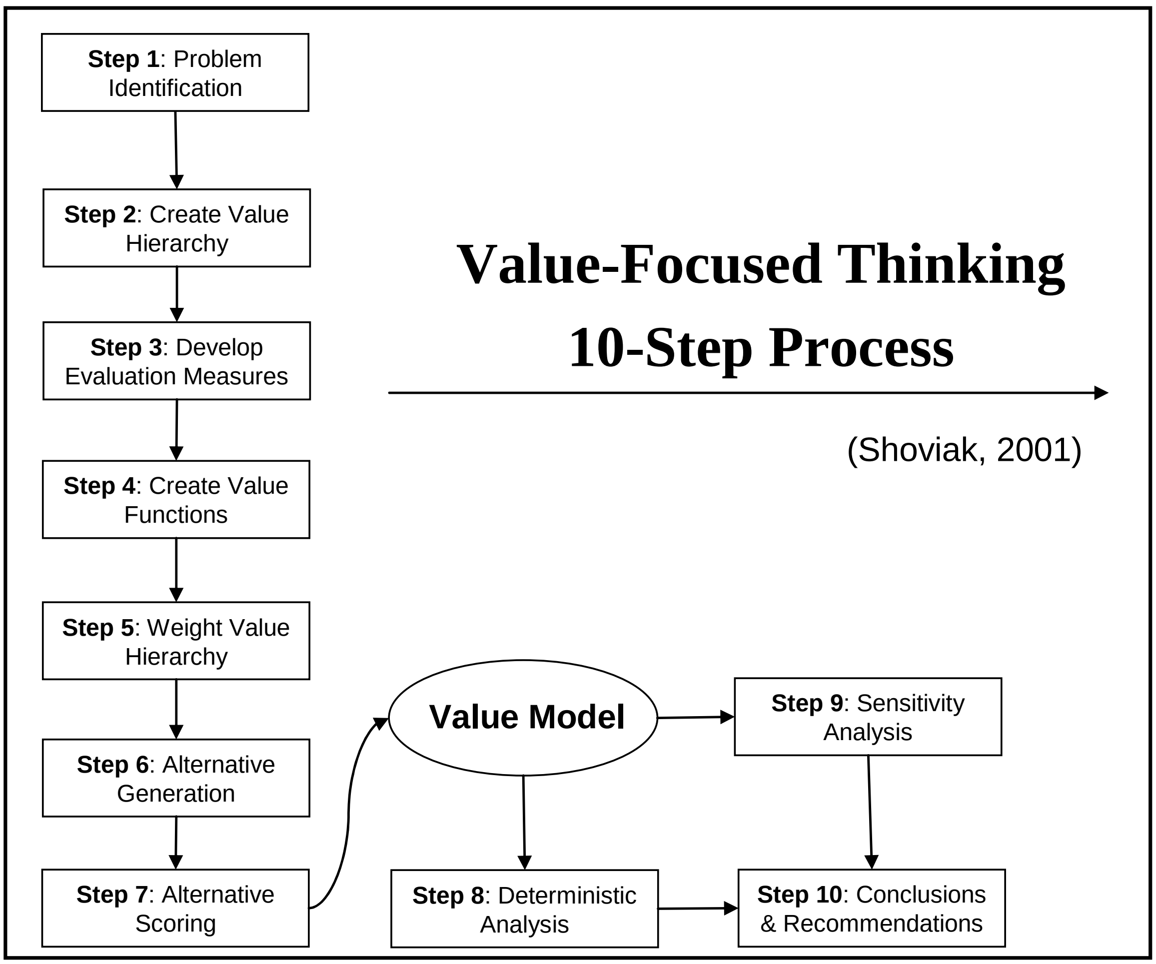


Figure 3.1. VFT 10-Step Process (Shoviak, 2001)

Steps 1 through 7 in the VFT process include the actual model development; therefore, they will be discussed in detail in this chapter. These stages of model development capture the results of the interaction between the stakeholders, also referred to as the decision-maker, and the model builder while formulating the VFT decision analysis tool or value model. Using the VFT framework for developing a decision analysis tool provides the model builder and the decision-maker a structured format for information exchange. For the purposes of this research, members of the 820th RED HORSE Squadron served as the proxy decision-maker to provide inputs for the model development. The proxy decision team members are listed in Appendix A. Steps 8 and 9, the deterministic and sensitivity analysis portions of the process, respectively, will be discussed in Chapter 4; step 10, conclusions and recommendations, will be addressed in Chapter 5.

3.1 Step 1 – Problem Identification

The first step in the VFT process is identifying the problem. Initial discussions with RED HORSE engineers resulted in the problem statement shown in Figure 3.2. This statement represents the fundamental objective for this VFT decision analysis model; as such, it is the top block in the value hierarchy. Keeney (1992:34) would call it the "ends objective" – it is the essential reason for the decision to be made.

Determine the most effective vertical contingency construction method in a deployed environment

Figure 3.2. Fundamental Objective

Within this fundamental objective statement, several key assumptions were made to limit the scope of the decision analysis model. First, this model assumes that RED HORSE personnel determine which construction method best meets their deployed needs. Second, this model limits the decision to vertical construction methods only. Vertical construction includes those methods above the ground, like buildings and facilities that provide cover from the natural elements. Horizontal construction like asphalt and concrete pavements, drainage systems, airfield lighting, etc., is not included. Last, the model is limited to contingency environments to emphasize the value of expediency in both the design and construction phases of a future project. Air Force contingencies that involve RED HORSE units typically include either agile combat support during times of war or prompt humanitarian aid following natural disasters.

3.2 Step 2 – Create Value Hierarchy

Step 2 of the VFT process, creating the value hierarchy, is perhaps the most critical in this thesis effort. This is the stage where the decision-maker determines what aspects of the decision are most important to meeting the fundamental objective. These values will later be used to evaluate the various alternatives to be analyzed by the model.

The model builder and the decision-maker can approach the value hierarchy development in two ways. If they already have a list of potential alternatives, they can start with the known alternatives and apply a "bottom-up" approach to creating the value hierarchy. In this approach, also called "alternatives driven," the stakeholder lists the alternatives first and sets out to determine how they differ. Values are added to the hierarchy to help differentiate between the known alternatives (Kirkwood, 1997:21-22). This method relies heavily on in-house knowledge of the building systems at their disposal. Furthermore, a bottom-up, alternatives driven approach limits the decision to only those alternatives pre-identified by the stakeholder.

Alternatively, a “top-down approach” can be used to create the value hierarchy. In this method, also called an “objectives driven” approach, the decision-maker first decides the primary objective. This objective is then iteratively broken down into evaluation considerations. A top-down approach best captures the value structure present in the stakeholder’s decision process and allows for multiple alternatives to be evaluated by the finished model (Kirkwood, 1997:21-22). The top-down approach was the method used in developing the value hierarchy for this thesis.

Once the fundamental objective was established, RED HORSE engineers were asked to brainstorm what they value in determining the optimal deployed vertical contingency construction method. These values were provided to the model builder, who categorized the inputs by similarity as shown in Table 3.1.

Table 3.1. Initial Value Inputs

- Construction
  - Man-hours
  - Equipment
  - Construction Time
- Materials
  - Cost
  - Availability
- Design
  - Mission/Use
  - Flexibility
  - Life Span
  - Expansion
  - Design Effort/Time
- Safety/Protection
  - Force Protection
  - Weather
  - Environmental Controls
- Transportability
  - Weight
  - Pallets
  - Delivery Time
  - Transportation Cost

The model builder and RED HORSE engineers discussed the value inputs and decided that some were either redundant or unnecessary. According to Kirkwood, a value hierarchy should be as small as possible to facilitate communication with interested parties and require fewer resources to estimate the performance of potential alternatives (Kirkwood, 1997:18). The value hierarchy must also be complete, non-redundant, independent, and operable, so that the overall objective of the decision can be achieved (Kirkwood, 1997:16-18). Thus, the changes shown in Appendix B were made to the value inputs to create the complete and operable value hierarchy. The 1st tier of the value hierarchy is shown in Figure 3.3.

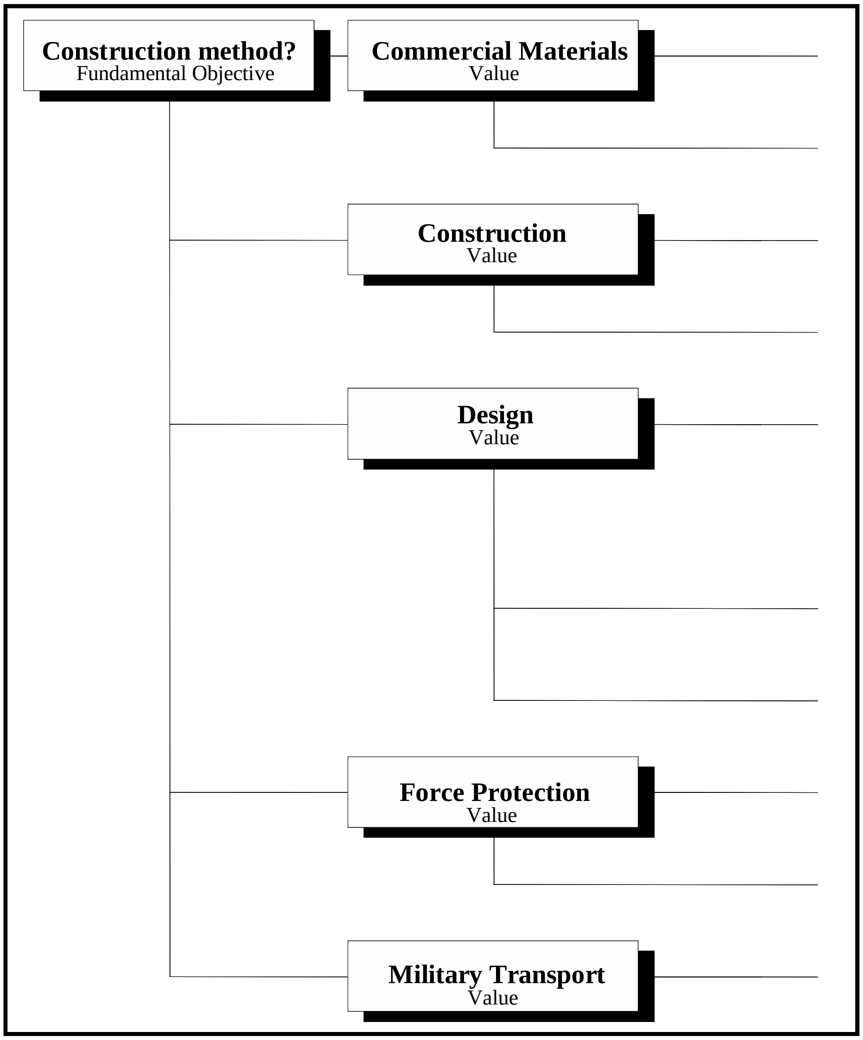


Figure 3.3. 1st Tier of Value Hierarchy

The 1st tier within the hierarchy represents the top-level values, i.e., the categories of evaluation criteria deemed the most important in deciding which construction alternative will best meet the fundamental objective. These 1st tier values are further refined into 2nd tier and 3rd tier values, as necessary, to more precisely define what performance characteristic they are intended to evaluate. The value hierarchy with every 1st, 2nd, and 3rd tier value is shown in Figure 3.4. To ensure the value hierarchy was clear and communicable, each value was defined; this information is shown in Table 3.2.

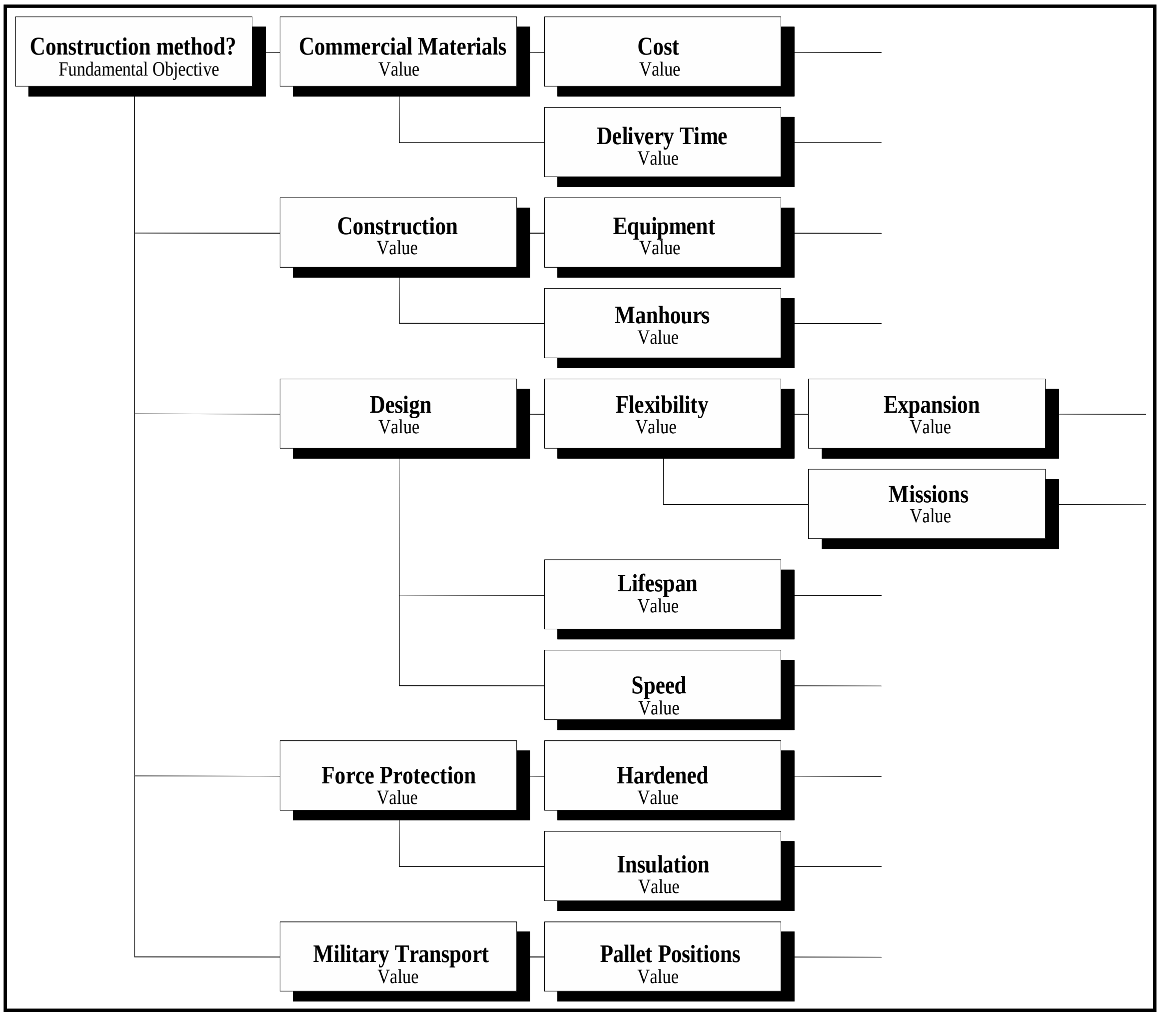


Figure 3.4. Value Hierarchy

Table 3.2. Value Definitions

Value	Definition
Design	The impact of speed, flexibility, and lifespan of this construction method to the RED HORSE engineering design effort.
Speed	The time it takes the RED HORSE design team to plan and design the facility using this construction method.
Flexibility	The adaptability of this construction method to accommodate multiple missions and situations.
Missions	The various types of USAF missions a facility built with this construction method alternative can accommodate.
Expansion	The ability to site adapt this construction method at the deployed location to increase or decrease the footprint of the facility.
Lifespan	The number of years of service this facility type is expected to provide at deployed location with minimal user maintenance.
Commercial Materials	The commercial cost and delivery time for the materials required to construct this facility type.
Cost	The total cost for RED HORSE to purchase this construction method from the vendor. This cost includes the cost of all materials and the cost of transportation of those materials from the vendor to RED HORSE.
Delivery Time	The time it takes the construction materials to reach RED HORSE once ordered from the vendor.
Military Transport	The ease with which this construction method can be transported by the USAF in a C-130 aircraft.
Pallet Positions	The number of USAF C-130 standard pallet positions required to transport the construction materials for this method further downrange from the vendor delivered location (transport beyond the commercial cost value).
Force Protection	The ability of this facility type to provide force protection and insulation for USAF personnel.
Hardened	The ability of this facility type to provide force protection against enemy attack.
Insulation	The R-value for this facility type (level of thermal insulation inherent to this type of facility).
Construction	The level of work required RED HORSE engineers to construct this type of facility.
Man-hours	The number of man-hours required to construct a facility of at least 3,000 square feet with this construction method.
Equipment	The type and number of heavy equipment pieces required to erect this type of construction method.

3.3 Step 3 – Develop Evaluation Measures

The next step in building the value model is developing the evaluation measures. Referred to as the measure of effectiveness or performance measure of an objective, evaluation measures are represented at the bottom of the value hierarchy (Kirkwood, 1997:12). The RED HORSE engineers and model builder developed the measures shown in Table 3.3 to evaluate the value objectives in the hierarchy. The measures are grouped under their respective first-tier value. The scale type, measure type, and lower and upper bounds are identified for each measure. For a complete definition of each measure see Appendix C. Figure 3.5 shows the final value hierarchy after the measures had been added as the lowest tier.

Table 3.3. Evaluation Measures

Value	Measure	Scale Type	Measure Type	Lower Bound	Upper Bound
Design					
Speed	Plan and Design Time	Natural Direct	Quantity	60 days	1 day
Flexibility	# of USAF Missions	Constructed Proxy	Category	Offices and Lodging Only	Aircraft, Vehicles, Warehouse, Offices and Lodging
Flexibility	Size Adaptable	Constructed Proxy	Category	Neither Modular nor Adaptable	Modular
Lifespan	Years of Service	Constructed Proxy	Category	Temporary	Permanent
Commercial Materials					
Cost	Cost of Materials	Natural Direct	Quantity	$40/square foot	$1/square foot
Delivery Time	Days for Delivery	Natural Direct	Quantity	60 days	7 days
Construction					
Equipment	Heavy Equipment	Constructed Proxy	Category	Beyond RHS Equipment Set	None Required
Manhours	# of Manhours	Natural Direct	Quantity	13,000 hours	75 hours
Force Protection					
Hardened	Hard or Soft Facility	Constructed Proxy	Category	Soft	Hardened
Insulation	R-Value	Natural Proxy	Quantity	0	19
Military Transport					
Pallet Positions	C-130 Pallet Positions	Constructed Proxy	Category	> 16 pallets	<= 4 pallets

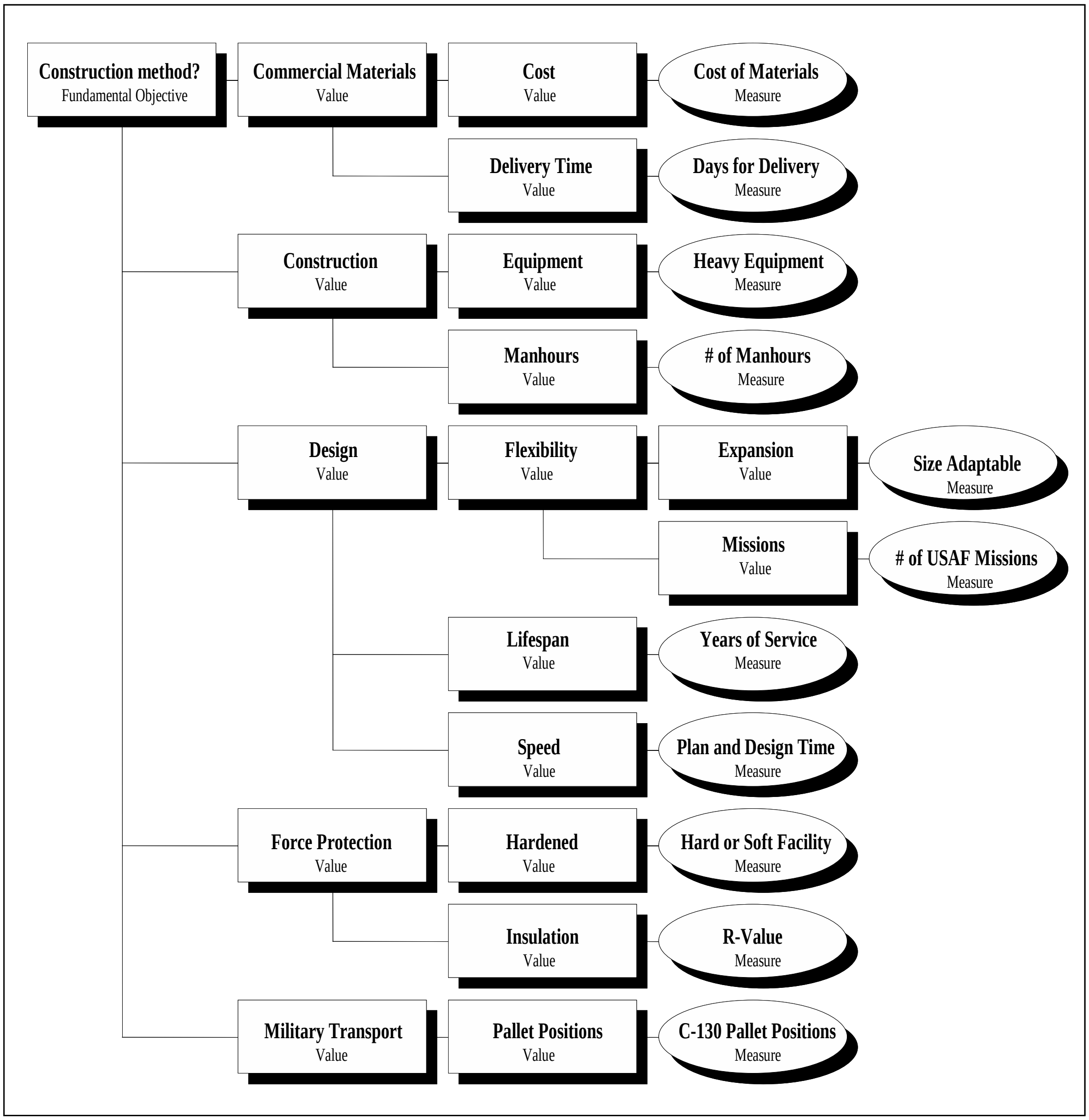


Figure 3.5. Final Value Hierarchy

3.4 Step 4 – Create Value Functions

In Step 4 of the VFT model building process, each evaluation measure included in the value hierarchy was converted into a single dimensional value function (SDVF). The SDVF is a value-specific function that translates the score for a value measure into a unit-less value between 0 and 1 which can be analyzed by the model (Kirkwood, 1997:53). By specifying an SDVF for each evaluation measure, the scores for every value measure within the model are standardized. Both discrete and continuous types of SDVFs were included in this model, and the SDVFs were either monotonically increasing or decreasing. An example of each type are shown in this chapter. The SDVFs for each value measure in the model are included in Appendix C with their respective evaluation measures.

Figure 3.6 shows the continuous monotonically increasing SDVF for the evaluation measure "R-Value." The range for the "R-Value" measure between the lower bound of 0 and upper bound of 19 is shown on the x-axis, and the unit-less value score is shown on the y-axis. The continuous monotonically increasing SDVF curve for "R-Value" indicates that higher amounts of x are preferred by the decision-maker. "R-Value" was the only evaluation measure in this model with a continuous monotonically increasing SDVF.

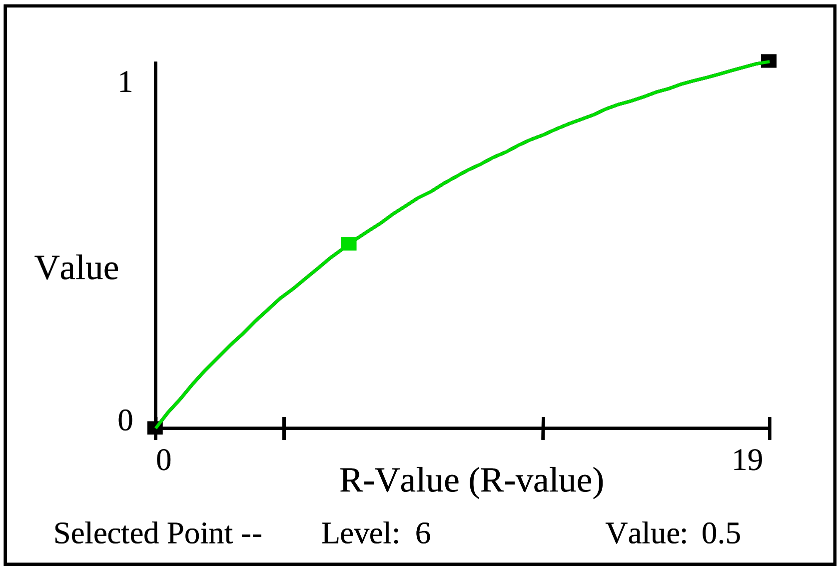


Figure 3.6. Monotonically Increasing SDVF for "R-Value"

Figure 3.7 shows the continuous monotonically decreasing SDVF for the evaluation measure "Plan and Design Time." For continuous monotonically decreasing SDVF curves, lower amounts of x are preferred by the decision-maker. For this example, notice that alternatives which take 1 day to plan and design score maximum value, and alternatives which take 60 days or longer to plan and design score 0 value for this evaluation measure. Evaluation measures "Cost of Materials," "Days for Delivery," "# of Manhours," and "Plan and Design Time" all had continuous monotonically decreasing SDVFs.

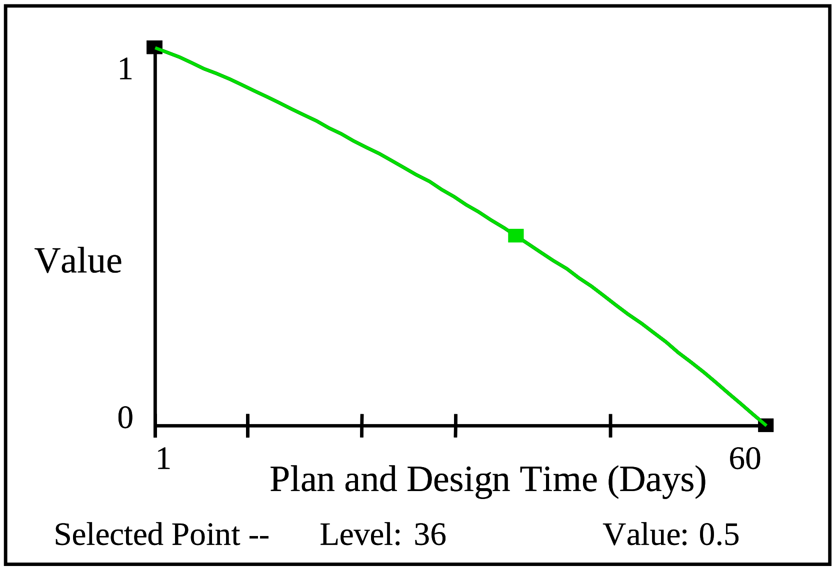


Figure 3.7. Monotonically Decreasing SDVF for “Plan and Design Time”

An example of a discrete categorical SDVF is shown in Figure 3.8 for the “Years of Service” evaluation measure. Discrete SDVF evaluation measures enable the decision-maker to group levels of value attainment into meaningful bins or categories. It is important that each category be clearly defined, so that the decision-maker can properly score alternatives for discrete evaluation measures.

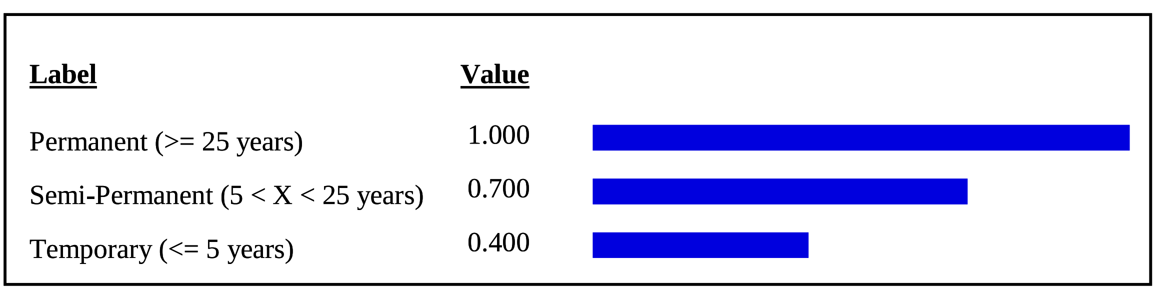


Figure 3.8. Discrete Categorical SDVF for “Years of Service”

The SDVF in each example translates the evaluation measure score into a value score. The sum of the value scores for each measure equal the final value score for each alternative.

3.5 Step 5 – Weight Value Hierarchy

After constructing the value hierarchy, to include tiered values and evaluation measures, Step 5 in the VFT process is weighting the value hierarchy (Shoviak, 2001). Since each value is not necessarily equal in importance to the decision-maker in achieving the fundamental objective, each value is given both a local weight and a global weight. As defined in Chapter 2, the local weight is the amount of weight a lower tier value contributes to the value directly above it in the hierarchy, and a global weight is each value's total contribution to the fundamental objective (Shoviak, 2001:57). The dotted ovals shown in Figure 3.9 demonstrate how a value tier is weighted.

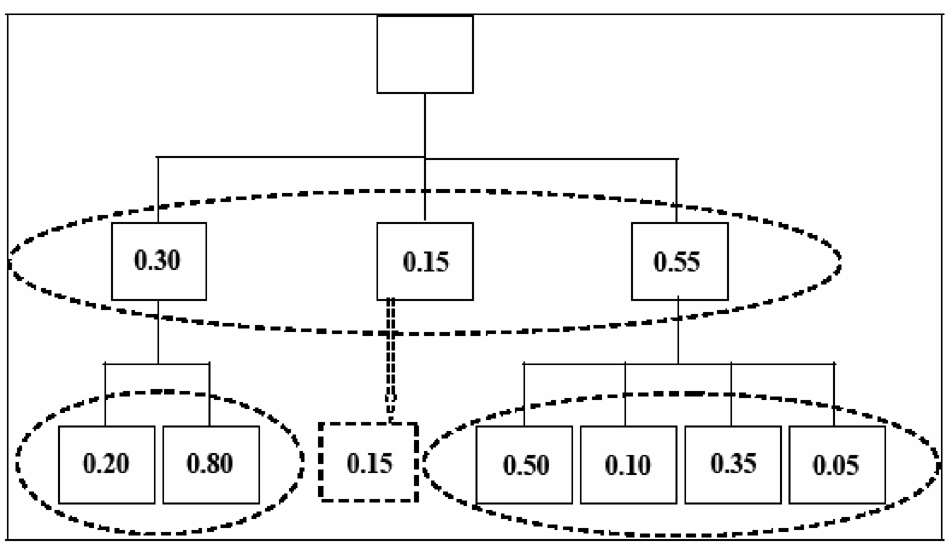


Figure 3.9. Generic Hierarchy Showing Local Weights Sum to One (Weir, 2004)

The “swing weighting” approach was used to assign an appropriate level of importance to each value. In this approach, the decision-maker started with the first tier of the hierarchy and determined that “Force Protection” was the least important to the fundamental objective. This value was given an importance factor of one. The remaining four values were then each given importance factors relative to “Force Protection.” “Construction” was considered to be four times as important as “Force Protection” and was given a factor of four. Using similar rationale, “Design” was given a factor of three, “Commercial Materials” a factor of two, and “Military Transport” a factor of one. Since the sum of these factors equals eleven, the local weights of each value were determined by dividing the individual factor of each value by eleven. The same process was then performed for the 2nd and 3rd tier values. The global weights were then determined by multiplying a value’s local weight by the local weight of the value directly above it in the hierarchy. In the case of the first tier values, their global weights are the same as their local weights, because the fundamental objective has value of 100 percent. The results of this exercise are shown in Table 3.4.

Table 3.4. Local and Global Weighting Table

		Local Weight	Global Weight
Fundamental Objective		100.00%	100.00%
1st Tier Values			
Values (Ranked Order)	**Importance Factor**	**Local Weight**	**Global Weight**
Construction	4	36.36%	36.36%
Design	3	27.27%	27.27%
Commercial Materials	2	18.18%	18.18%
Military Transport	1	9.09%	9.09%
Force Protection	1	9.09%	9.09%
Subtotal	11	100.00%	100.00%
2nd Tier Values			
Values (Ranked Order)	**Importance Factor**	**Local Weight**	**Global Weight**
Construction			
Manhours	3	75.00%	27.27%
Equipment	1	25.00%	9.09%
Subtotal	4	100.00%	36.36%
Design			
Flexibility	4	57.14%	15.58%
Lifespan	2	28.57%	7.79%
Speed	1	14.29%	3.90%
Subtotal	7	100.00%	27.27%
Commercial Materials			
Cost	2	66.67%	12.12%
Delivery Time	1	33.33%	6.06%
Subtotal	3	100.00%	18.18%
Military Transport			
C-130 Pallet Positions	1	100.00%	9.09%
Subtotal	1	100.00%	9.09%
Force Protection			
Hardened	3	75.00%	6.82%
Insulation	1	25.00%	2.27%
Subtotal	4	100.00%	9.09%
3rd Tier Values			
Values (Ranked Order)	**Importance Factor**	**Local Weight**	**Global Weight**
Flexibility			
Missions	2	66.67%	10.39%
Expansion	1	33.33%	5.19%
Subtotal	3	100.00%	15.58%

3.6 Step 6 – Alternative Generation

After weighting the value hierarchy, the decision-maker identified eight alternatives representing a diverse group of both traditional and innovative contingency construction methods. These methods were concrete masonry unit (CMU), K-Span, pre-engineered building (PEB), tilt-up reinforced concrete, plastic finished concrete forms developed by Royal Building System (RBS), Alaska Small Shelter System (AKSSS), California Shelter, and Tent Extendable Modular Personnel Tent (TEMPER Tent). RED HORSE personnel then collected and presented raw data for each of the evaluation measures within the model for each construction method. Table 3.5 is a summary of the raw data for each alternative; it is based on the decision-maker's knowledge and experience of working with these construction methods in the field.

Table 3.5. Raw Data for Eight Alternatives

Evaluation Measure	PEB	K-Span	CMU	Tilt-Up	RBS	TEMPER Tent	Alaska	California
Construction								
Manhours (Hours)	8400	6300	12000	9600	8100	75	108	144
Heavy Equipment	Within	Within	Within	Beyond	Within	None	None	Within
Design								
Lifespan (Years)	30	10	30+	30+	30+	2	2	5
Speed (Days)	30	10	21	45	10	1	1	1
Missions (Types)	All	All	No Aircraft	All	No Aircraft	Office and Lodging	Office and Lodging	No Aircraft
Expansion (System)	Neither	Modular	Adaptable	Adaptable	Adaptable	Modular	Modular	Adaptable
Commercial Materials								
Cost ($/SF)	20	12	30	18	9	3	4	5
Delivery Time (Days)	40	18	60	60	30	7	7	14
Military Transport								
C-130 Pallet Positions	10	8	4	4	4	1	1	2
Force Protection								
Hardened	Soft	Soft	Hard	Hard	Hard	Soft	Soft	Soft
Insulation (R-Value)	19	4	4	12	12	0	4	4

3.7 Step 7 - Alternative Scoring

Step 7 in the VFT process is scoring the alternatives (Shoviak, 2001). Table 3.6 shows the data for each of the eight construction methods in relation to the evaluation measures. Data for continuous measures was input directly. For example, according to the data, it takes 21 days for RED HORSE engineers to plan and design a CMU facility. Since the "Plan and Design Time" measure is continuous, 21 days was directly input into the value model. Data for discrete measures was input according to the appropriate category within that measure. For example, according to the data, a CMU facility requires four C-130 pallet positions for military transport. Since "C-130 Pallet Positions" is a discrete measure, the appropriate category within that measure was "<= 4 (1 Aircraft)."

Table 3.6. Value Model Data for the Eleven Measures of the Eight Alternatives

Alternative	# of Manhours	USAF Missions	C-130 Pallet Positions	Cost of Materials
Alaska Small Shelter	108	Offices and Lodging Only	<= 4 (1 Aircraft)	4
California Shelter	144	Vehicles, Warehouse, Offices, and Lodging	<= 4 (1 Aircraft)	5
CMU	12000	Vehicles, Warehouse, Offices, and Lodging	<= 4 (1 Aircraft)	30
K-Span	6300	Aircraft, Vehicles, Warehouse, Offices, and Lodging	4 < X <= 8 (2 Aircraft)	12
PEB	8400	Aircraft, Vehicles, Warehouse, Offices, and Lodging	8 < X <= 12 (3 Aircraft)	20
RBS	8100	Vehicles, Warehouse, Offices, and Lodging	<= 4 (1 Aircraft)	9
TEMPER Tent	75	Offices and Lodging Only	<= 4 (1 Aircraft)	3
Tilt-Up	9600	Aircraft, Vehicles, Warehouse, Offices, and Lodging	<= 4 (1 Aircraft)	18

Alternative	Days for Delivery	Hard or Soft Facility	Heavy Equipment	Plan and Design Time	R-Value	Size Adaptable	Years of Service
Alaska Small Shelter	7	Soft	None Required	1	4	Modular	Temporary (<= 5 years)
California Shelter	14	Soft	Within RHS Equipment Set	1	4	Adaptable	Temporary (<= 5 years)
CMU	60	Hardened	Within RHS Equipment Set	21	4	Adaptable	Permanent (>= 25 years)
K-Span	18	Soft	Within RHS Equipment Set	10	4	Modular	Semi-Permanent (5 < X < 25 years)
PEB	40	Soft	Beyond RHS Equipment Set	30	19	Neither	Semi-Permanent (5 < X < 25 years)
RBS	30	Hardened	Within RHS Equipment Set	10	12	Adaptable	Permanent (>= 25 years)
TEMPER Tent	7	Soft	None Required	1	0	Modular	Temporary (<= 5 years)
Tilt-Up	60	Hardened	Beyond RHS Equipment Set	45	12	Adaptable	Permanent (>= 25 years)

After inputting the required data for each alternative into the value model, the value scores were determined. Scoring an alternative is the process of selecting the appropriate value from the *x*-axis or category of each SDVF shown in Appendix C (Mayer, 2004). Each alternative's value score for each measure was calculated by the model using the value functions and weights created by the decision-maker in steps 3, 4, and 5. The model then applied the additive value function, explained in Chapter 2, to calculate the total value scores for every alternative. The value scores for each alternative are presented and discussed in Chapter 4.

3.8 Summary

This chapter explained the application of the value focused thinking methodology used in this thesis to construct a decision analysis tool to help RED HORSE engineers determine the best contingency construction method for a particular deployed location. The specific and iterative actions taken by the model builder and decision-maker as outlined in steps 1-7 of Shoviak's (2001) 10-Step VFT process were explained in detail. The decision team identified the problem; developed the value hierarchy, evaluation measures, and SDVFs; weighted the value hierarchy; generated alternatives; and scored the alternatives. Chapter 4 presents the alternative scoring results and discusses the deterministic and sensitivity analysis of the value model.

4. Results and Analysis

This chapter presents the deterministic and sensitivity analyses for the eight alternatives evaluated by the value model created for the Rapid Engineering Deployable, Heavy Operation Repair Squadron, Engineer (RED HORSE). Step 8 in the Value Focused Thinking (VFT) process, the deterministic analysis, includes the calculation and evaluation of the total value scores for each alternative and provides insight for the decision-maker as to why the top-ranked alternative scored higher than the other alternatives (Mayer, 2004:68). Sensitivity analysis, step 9 in the VFT process (Shoviak, 2001), illustrates how the decision-maker's weighting of the value hierarchy effects the alternative rankings. Sensitivity breakeven graphs are presented and explained that indicate how the alternatives' total value scores change based on adjustments to the weighting of the individual values and measures within the value model.

4.1 Deterministic Analysis

The total value scores calculated by the model are shown and ranked in Figure 4.1. The eight construction methods included in this research were concrete masonry unit (CMU), K-Span, pre-engineered building (PEB), tilt-up reinforced concrete, plastic finished concrete forms developed by Royal Building System (RBS), Alaska Small Shelter System (AKSSS), California Shelter, and Tent Extendable Modular Personnel Tent (TEMPER Tent). According to the value model, RBS is the best alternative with a score of 80.9%. California Shelter ranks second with 79.4%, followed very closely by Alaska Small Shelter with 79.2% total value and TEMPER Tent with 78.6%. Then comes K-Span at 75.7% and Tilt-Up at 65.7%. At the bottom of the ranking are PEB and CMU with total value scores of 55.6% and 55.5%, respectively.

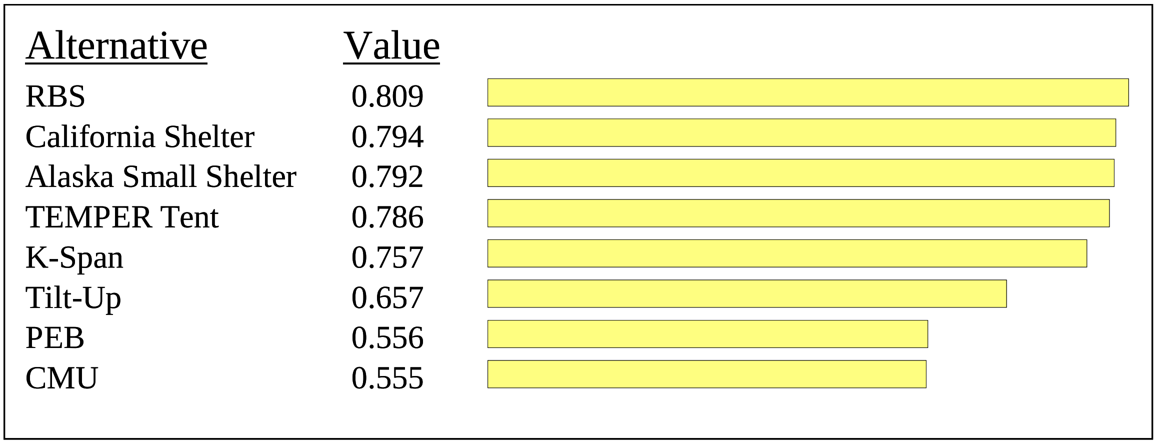


Figure 4.1. Ranked Total Value Scores for Eight Alternatives

Figure 4.2 is a stacked bar chart of the total value score of each alternative showing how the alternatives scored in each of the five first-tier values. A hypothetical optimum alternative is included at the top of the chart to show the maximum achievable score for each value.

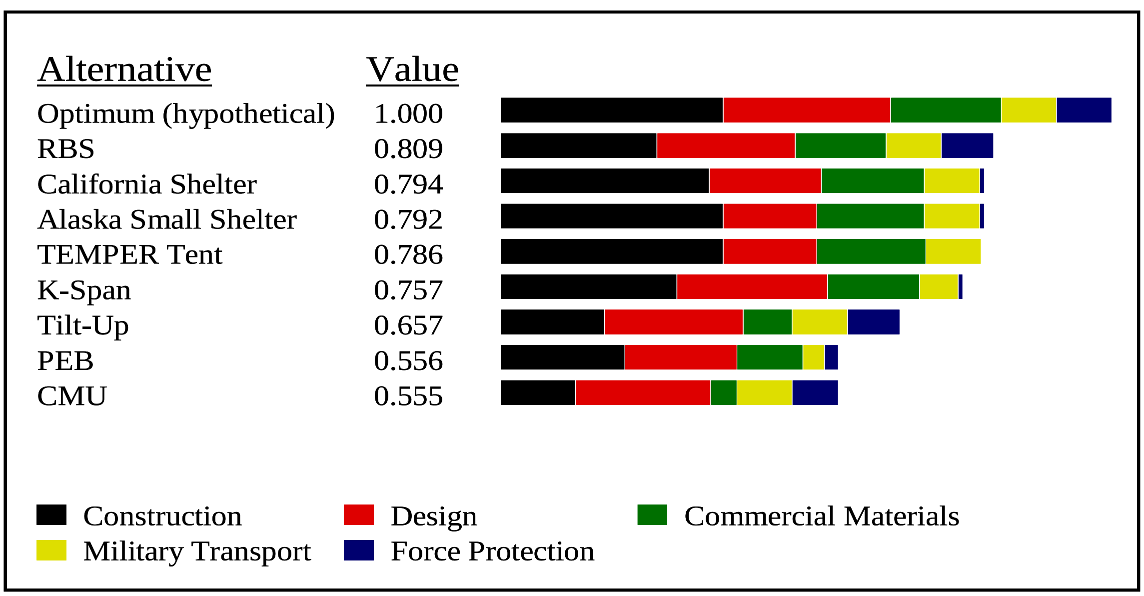


Figure 4.2. Alternatives' Total Value Ranking by Top Five Values

"Construction" is the value with the highest weighting (36.4%) and is the first value shown in the stacked bars. Alaska Small Shelter and TEMPER Tent both achieved the maximum score (i.e., value) for "Construction." California Shelter scored almost as well in this value, while CMU scored the least. "Design" is the second value shown in the stacked bars with a weighting of 27.3%. All of the alternatives scored reasonably well in this value. "Commercial Materials" has the third highest weighting (18.2%) and is shown next. The top five alternatives scored well for this value; CMU scored the worst. The last two values in the stacked bars, "Military Transport" and "Force Protection," both have the same weighting (9.1%). Except for K-span and PEB, the other alternatives scored the maximum value for "Military Transport;" PEB scored the least. Finally, for the "Force Protection" value, RBS and Tilt-Up scored the best followed closely by CMU. TEMPER Tent scored zero for this value.

The first-tier values were further refined into lower tier values and eventually the measures. Examining the value scores for each alternative in terms of the measures provides more detail on where the alternatives gained value within the model as shown in Figure 4.3. The alternatives were again ranked by their total value scores with the hypothetical optimum alternative at the top.

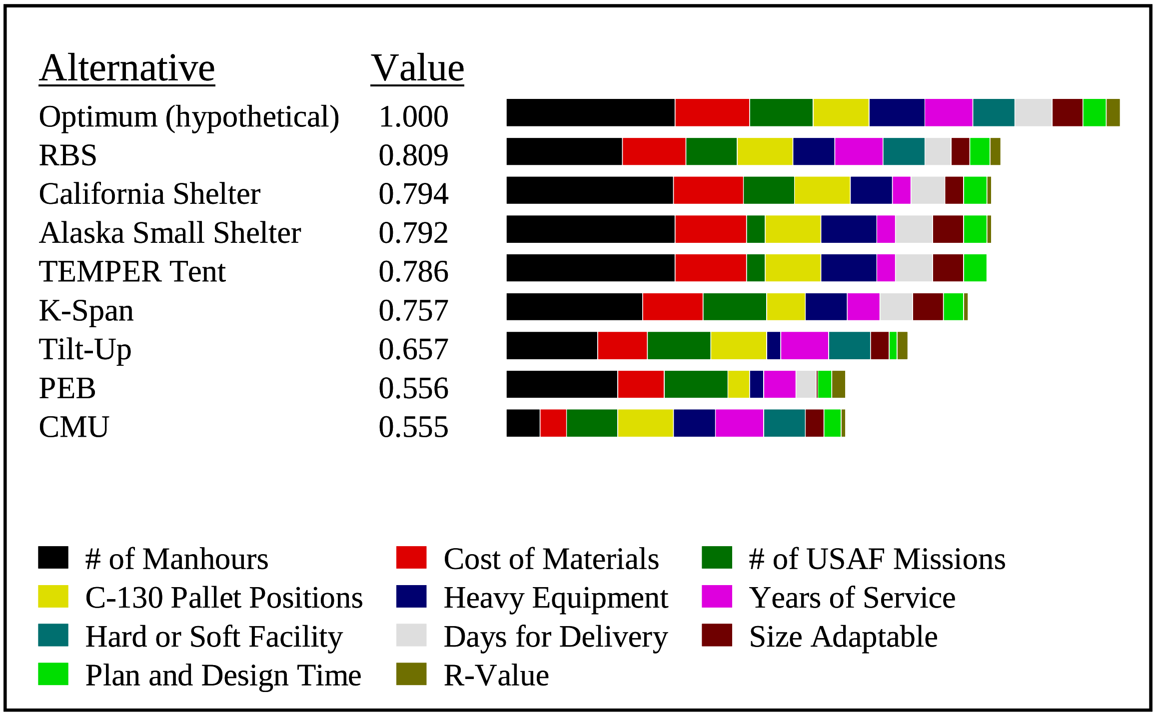


Figure 4.3. Alternatives' Total Value Ranking by Eleven Measures

The Alaska Small Shelter System and TEMPER Tent both scored the maximum value in the "# of Manhours" and "Heavy Equipment" measures, which corresponds to their dominance in the "Construction" value illustrated in Figure 4.2. This was expected, since they are fabric covered frame tent structures that require no heavy equipment support and minimal manhours to erect. California Shelter, another fabric frame tent system, also scored high in both of these measures. RBS and K-Span scored less value for the "Heavy Equipment" measure and the "# of Manhours" measure than the three fabric frame tent systems, but they scored greater value in these measures than the bottom three alternatives. CMU, a labor-intensive construction method, scored poorly in "# of Manhours" but did well in "Heavy Equipment." Conversely, Tilt-Up and PEB, which both require greater heavy equipment support, scored better than CMU in "# of Manhours" but worse in "Heavy Equipment."

Other insights include the fact that PEB scored the least value among the alternatives for the "C-130 Pallet Positions" measure, which is primarily because PEBs are transported to a construction site in large pre-fabricated sections. Additionally, Tilt-Up and CMU, which require lengthy delivery time, both scored zero for the "Days for Delivery" measure. As expected, the TEMPER Tent was the only alternative to receive no value for the "R-Value" measure. Similarly, five alternatives received no value for the discrete all or nothing "Hard or Soft Facility" measure; the other three alternatives (RBS, Tilt-Up, and CMU) scored the maximum value. PEB scored very low in the "Size Adaptable" measure because it is neither modular nor size adaptable at a project location without major redesign. Finally, Tilt-Up scored the lowest in the "Plan and Design Time" measure of all the alternatives.

The greatest insight gained from this deterministic analysis is that RBS achieved the highest total value score of the eight alternatives evaluated in this model. Even though RBS did not outscore the other alternatives in every measure, nor dominate any single top-tier value, RBS did score well in every measure and performed well in every value. This consistency resulted in its total value score of 80.9% and the top ranking. However, this does not imply that RBS is the "best" alternative for every contingency construction situation; it simply means that RBS achieved the highest value score for the specific value model weighting applied for this scenario. See Appendix D for value charts comparing RBS with the other alternatives individually.

Since the top five alternatives have total value scores in relative proximity to each other, it is useful to review the global weights for the measures again. The global weights for the eleven measures are shown in Table 4.1 in descending order. With a global weight of 27.3%, the "# of Manhours" measure has by far the greatest share of the total value within the model. The "Cost of Materials" and "# of USAF Missions" measures, with global weights of 12.1% and

10.4%, respectively, also have significant value shares. Combined, these three measures comprise nearly 50% of the value within the model. The close proximity of the scores for the top-ranked alternatives also indicates that the deterministic results of this value model could be highly sensitive to changes in the weighting of the value hierarchy. Therefore, sensitivity analysis will be performed on each value branch within the hierarchy to provide greater insight to the decision-maker regarding the impact of the weights on the alternative rankings.

Table 4.1. Global Weights of the Evaluation Measures

Measure	Global Weight (%)	Cumulative Weight (%)
# of Manhours	27.3	27.3
Cost of Materials	12.1	39.4
# of USAF Missions	10.4	49.8
Heavy Equipment	9.1	58.9
C-130 Pallet Positions	9.1	68
Years of Service	7.8	75.8
Hard or Soft Facility	6.8	82.6
Days for Delivery	6.1	88.7
Size Adaptable	5.2	93.9
Plan and Design Time	3.9	97.8
R-Value	2.3	100

4.2 Sensitivity Analysis

Sensitivity analysis allows the decision-maker to vary the weight of a value or measure within the value hierarchy and observe the impact on the value score rankings of the alternatives. The weight of a single value is varied from 0% to 100% of the total model value, while keeping all other value weights proportional. The impact this has on the ranking of the alternatives' final value scores is displayed on a breakeven chart for analysis. Sensitivity analysis was performed on each of the major branches (i.e., top-tier values) of the value hierarchy; if any of these values were considered sensitive to changes in the weights, the sensitivity analysis process was applied to the respective second-tier values.

4.2.1 Sensitivity Analysis of the "Construction" Branch

The "Construction" value branch shown in Figure 4.4 comprises the lower tier values of "Equipment" and "Manhours." These second-tier values were evaluated by the "Heavy Equipment" and "# of Manhours" measures, respectively. Since the global weight for the "Construction" branch is 36.4%, the highest of any of the first-tier branches in the model, sensitivity analysis is performed on it first.

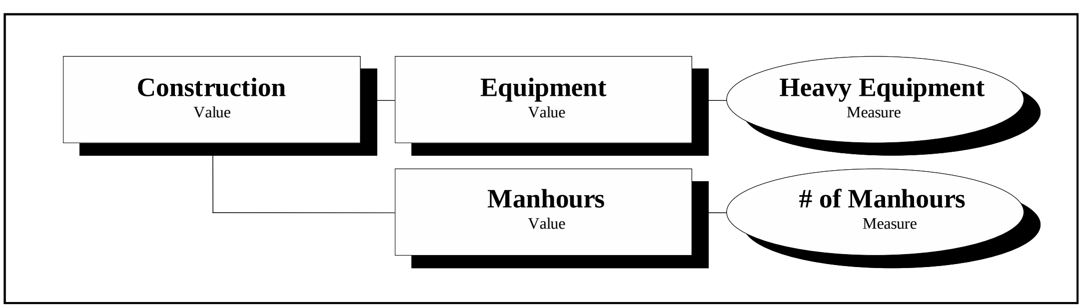


Figure 4.4. Construction Value Branch

Figure 4.5 is a breakeven chart for the "Construction" value with the percentage weight of the value shown on the *x*-axis and the total value score of the alternatives shown on the *y*-axis. The current global weight for "Construction" is indicated by the vertical line at 36.4%. The point at which this vertical line crosses each alternative's plotted line equates to the alternative's total value score at this weight. Furthermore, the order of the alternatives in the legend matches the order of the plotted lines when the value has a weight of 100% (i.e., along the right vertical axis). With "Construction" weighted at 36.4%, RBS is the top ranked alternative. As the weight is decreased, RBS remains the top alternative; in fact, its separation from its nearest competitors increases. However, if the weight increases to about 40%, the top 4 alternatives are essentially equal in value. As the weight increases past 40%, the value of RBS continues to decrease and Alaska Small Shelter and TEMPER Tent become the best alternatives. "Construction" was considered sensitive to weight increases.

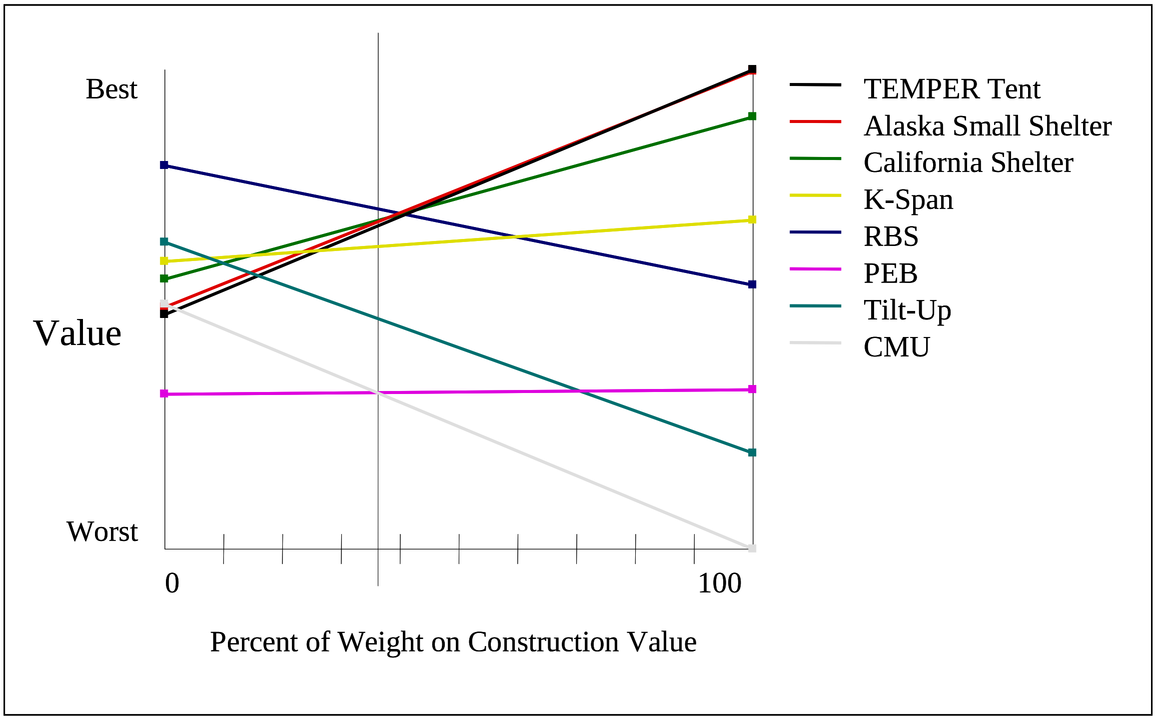


Figure 4.5. Sensitivity Analysis of Construction Value Objective

Since the “Construction” value was considered sensitive, sensitivity analysis was also performed on the second-tier values of “Equipment” and “Manhours” to gain further insight into the sensitivity of this value branch. Figures 4.6 and 4.7 are the breakeven charts for the sensitivity analysis of these values, respectively. RBS is the best alternative with the “Equipment” value weighted at 9.1%. If the weight is increased to about 15%, then Alaska Small Shelter becomes the top ranked alternative followed very closely by TEMPER Tent. The superior performance of Alaska Small Shelter and TEMPER Tent in the value of “Equipment” is indicated by their positively sloping curve. This was expected, since these methods require no heavy equipment support during construction. Beyond 15% weight, RBS remains the third best alternative. Like the “Construction” value, “Equipment” is insensitive to a decrease in the global weight.

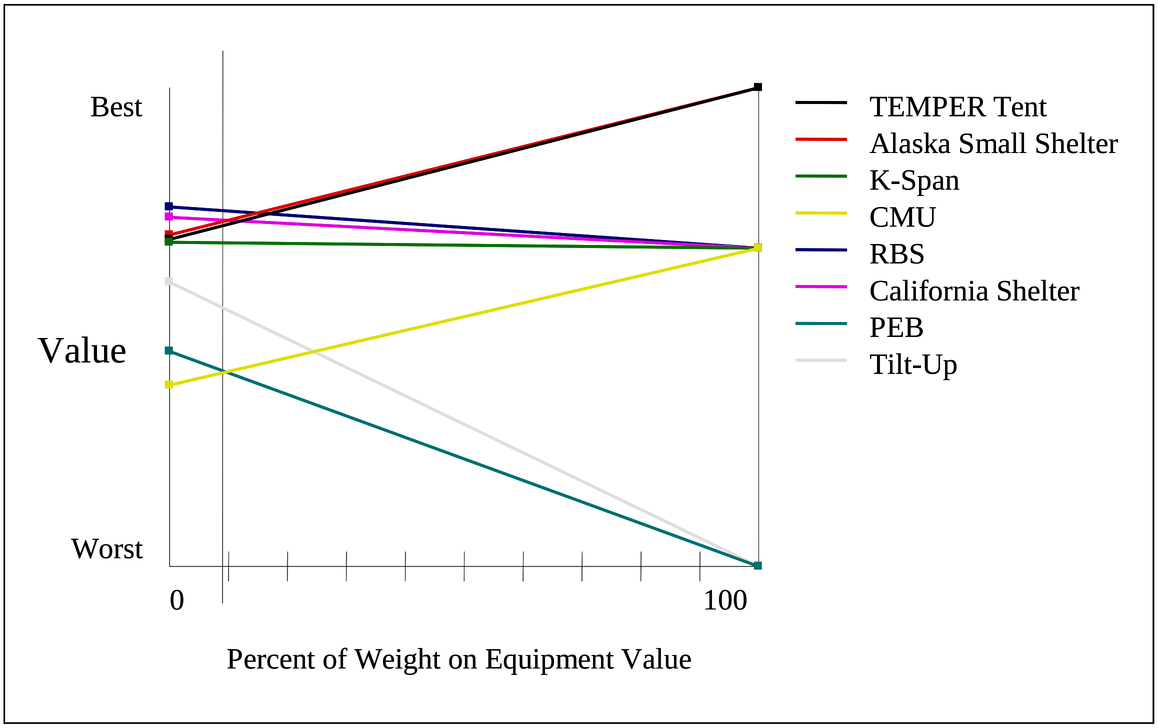


Figure 4.6. Sensitivity Analysis of Equipment Value Objective

In Figure 4.7, RBS is the best alternative with the "Manhours" value weighted at 27.3%. Increasing the weight to about 31% drops RBS to the fourth ranked alternative behind California Shelter, Alaska Small Shelter, and TEMPER Tent. If the weight is further increased to about 50%, K-Span begins to receive more value than RBS; thus, RBS drops to the fifth-ranked alternative.

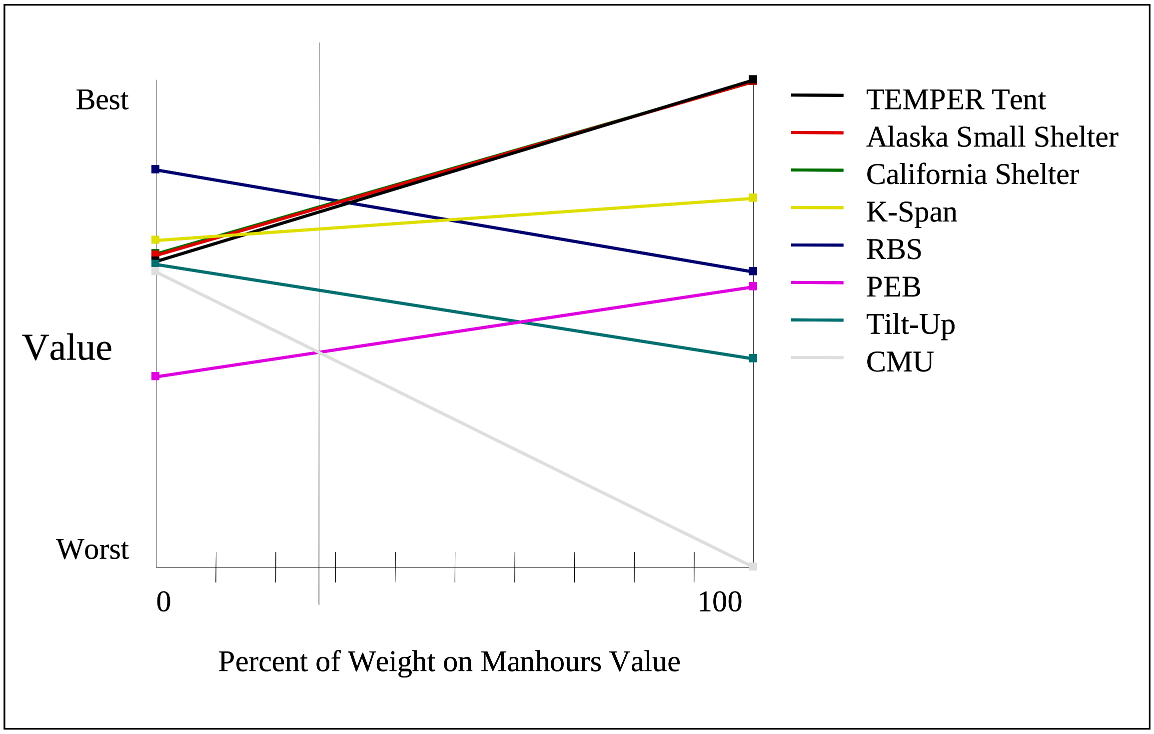


Figure 4.7. Sensitivity Analysis of Manhours Value Objective

From this analysis, it is clear that both second-tier values in the "Construction" branch are sensitive to changes in the global weights. RBS is the best alternative as long as the weighting of both the "Equipment" and "Manhours" values remain at or below current levels. However, with slight increases to the weighting of either value, the fabric covered frame type construction methods (Alaska Small Shelter, TEMPER Tent, and California Shelter) overtake RBS as the top ranked alternatives. Thus, the "Construction" value branch appears to be sensitive to weight increases but insensitive to weight decreases. Since "Construction" is already by far the highest weighted value in the hierarchy, it is unlikely that the decision-maker would further increase the weighting of this value. Additional insight gained from the sensitivity analysis is the observation that Tilt-Up, PEB, and CMU never approach becoming the best alternative, regardless of the weight assigned to either "Equipment" or "Manhours." This reinforces the fact that these construction methods are either labor intensive and/or require significant heavy equipment support.

4.2.2 Sensitivity Analysis of the "Design" Branch

"Design" is the second highest weighted top-tier value in the hierarchy with a combined global weight of 27.3%. Figure 4.8 shows the composition of the "Design" branch with its lower-tier values and measures. For the second-tier values, "Flexibility" has a global weight of 15.6%, "Lifespan" a global weight of 7.8%, and "Speed" a global weight of 3.9%. "Flexibility" is further broken out into the third-tier values of "Expansion" and "Missions" with global weights of 5.2% and 10.4%, respectively.

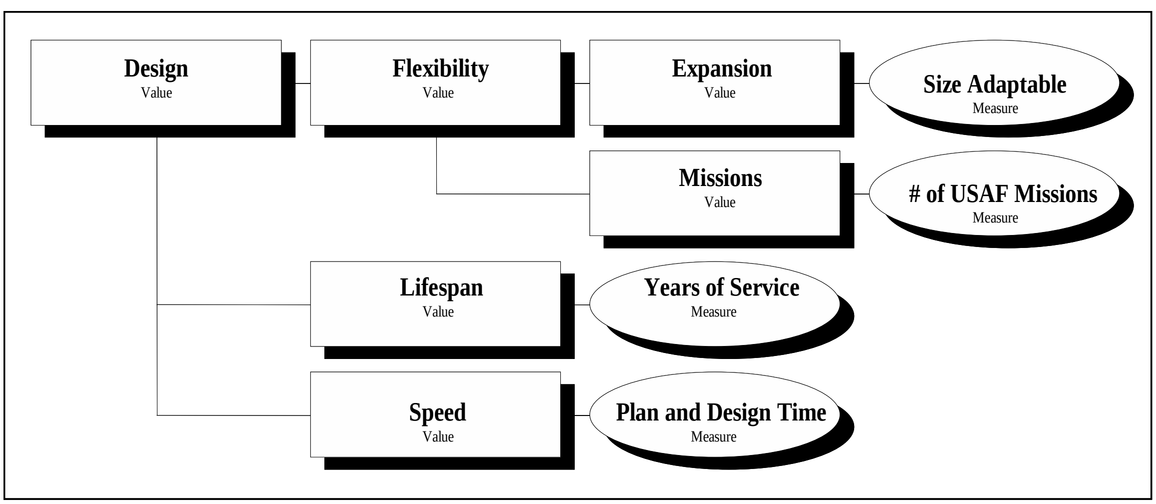


Figure 4.8. Design Value Branch

Figure 4.9 is a breakeven chart for the sensitivity analysis of the "Design" value. RBS is the top ranked alternative when "Design" is weighted at 27.3% of the total model value.

Decreasing the weight of “Design” from 27.3% to about 22% or below makes Alaska Small Shelter the most preferred alternative. Further decreasing the weight to about 20% makes TEMPER Tent the second best alternative and California Shelter the third best, thereby dropping RBS to fourth. Increasing the weight of “Design” to almost 60% or more makes K-Span the most preferred alternative, with RBS remaining as the second best alternative and Tilt-Up becoming the third best. The “Design” value was considered highly sensitive to both increasing and decreasing weight.

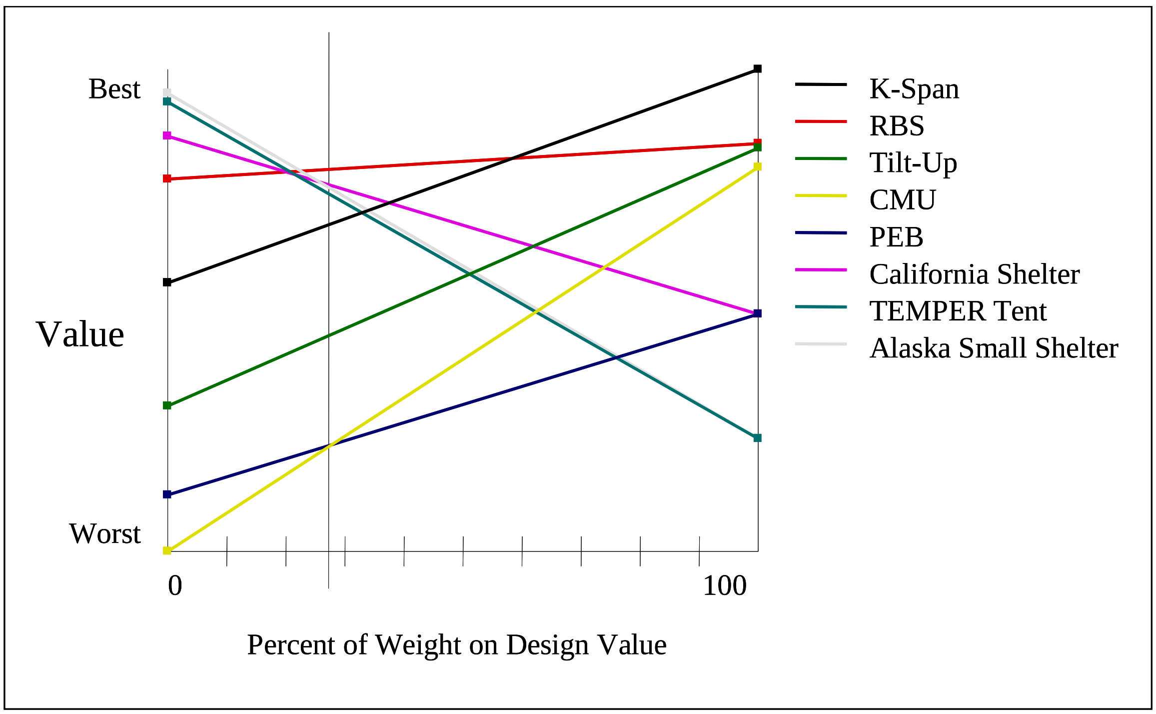


Figure 4.9. Sensitivity Analysis of Design Value Objective

Since the “Design” value was considered sensitive, its second-tier values were examined for sensitivity as well. Figures 4.10, 4.11, and 4.12 are the breakeven charts for the sensitivity analysis of “Flexibility,” “Lifespan,” and “Speed,” respectively. Figure 4.10 indicates that RBS is the top ranked alternative when “Flexibility” is weighted at 15.6% of the total value within the model. Furthermore, RBS remains the top ranked alternative as long as the weight is between 6% and 30%. Therefore, “Flexibility” is considered moderately insensitive. Below 6%, Alaska Small Shelter is the most preferred alternative, and above 30%, K-Span is the most preferred. The steep positive slope of K-Span, and its clear dominance over the other alternatives beyond a weighting of 30%, indicates that K-Span scores very well in “Flexibility.” Tilt-Up has a similar slope and becomes the second ranked alternative beyond a weighting of about 60% in this value. Since the “Flexibility” value is considered moderately insensitive, the sensitivity analyses for its third-tier values are shown in Appendix E.

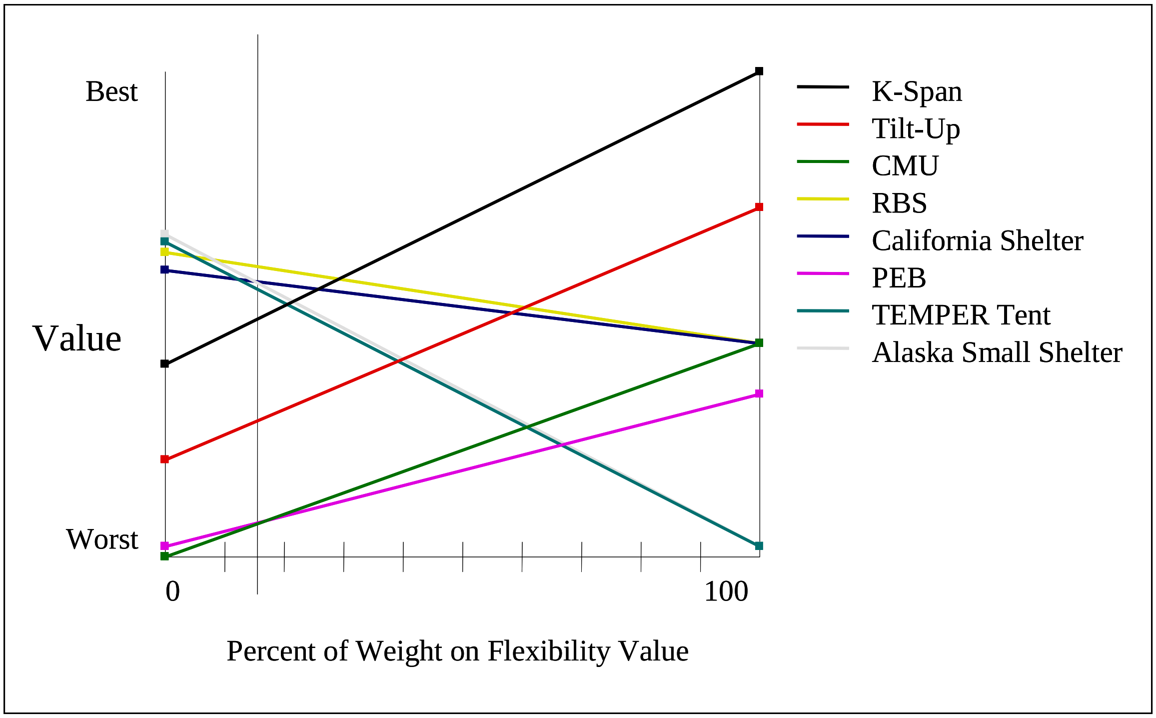


Figure 4.10. Sensitivity Analysis of Flexibility Value Objective

"Lifespan" and "Speed" are the two remaining second-tier values within the "Design" branch. Figure 4.11 shows the breakeven chart for the sensitivity analysis of the "Lifespan" value, which shows that RBS is the best alternative when the global weight is 7.8% for this value. Decreasing the weight of "Lifespan" to about 5% or less makes California Shelter, Alaska Small Shelter, and TEMPER Tent better alternatives than RBS. For this reason, "Lifespan" is considered sensitive only to weight decreases. "Lifespan" is mostly insensitive, however, to any increase in weighting. The sharply decreasing slopes of the three fabric type construction methods (California Shelter, Alaska Small Shelter, and TEMPER Tent) indicate that their value to the decision-maker drops significantly as longer facility life is required. Conversely, the three concrete alternatives (CMU, Tilt-up, and RBS) perform very well in this value as indicated by their positively sloping curves. Should the decision-maker choose to weight “Lifespan” at 100%, then the three concrete alternatives would share the top ranking.

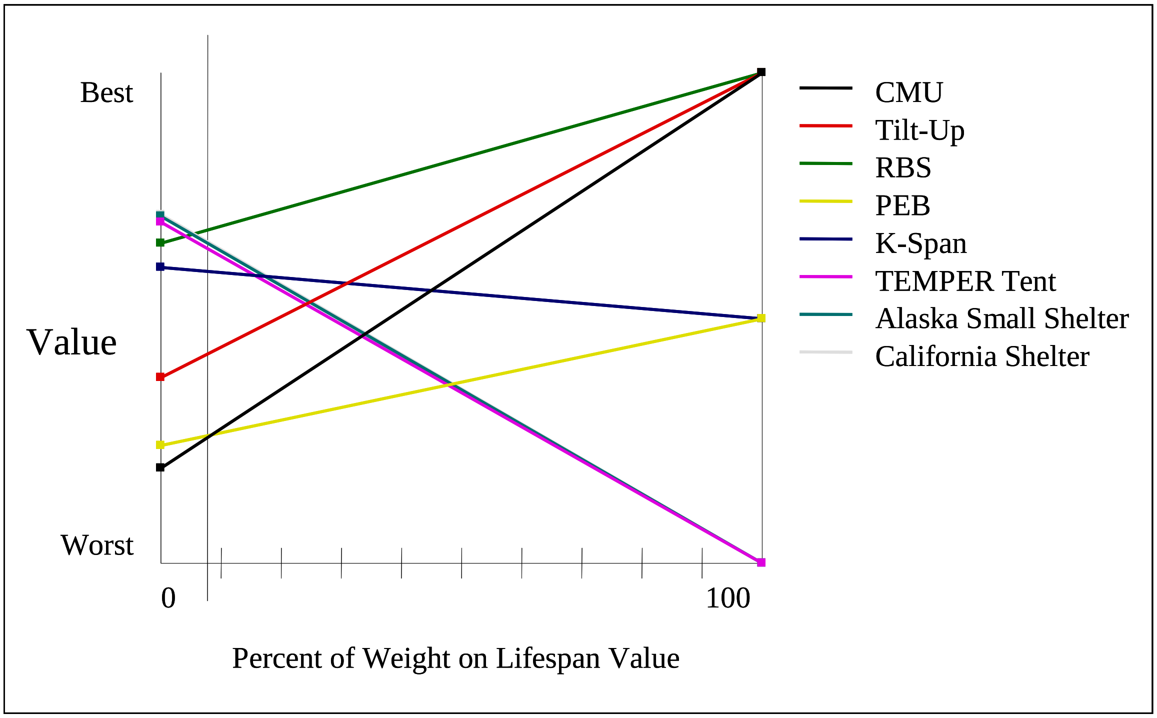


Figure 4.11. Sensitivity Analysis of Lifespan Value Objective

Figure 4.12 shows the breakeven chart for the sensitivity analysis of the “Speed” value. RBS is the preferred alternative when the global weight is 3.9% for this value. RBS retains the top ranking as long as this value is weighted between 0% to about 13%. Therefore, the value is considered moderately insensitive. However, if the weight of “Speed” is increased to 13% or more, then the better alternatives become California Shelter, Alaska Small Shelter, and TEMPER Tent. This was not surprising since the fabric type facilities require only one day to plan and design. It is interesting to note that Tilt-Up is the only alternative with a decreasing slope. This implies that Tilt-Up provides little value to the decision-maker in situations when expedient planning and design is required.

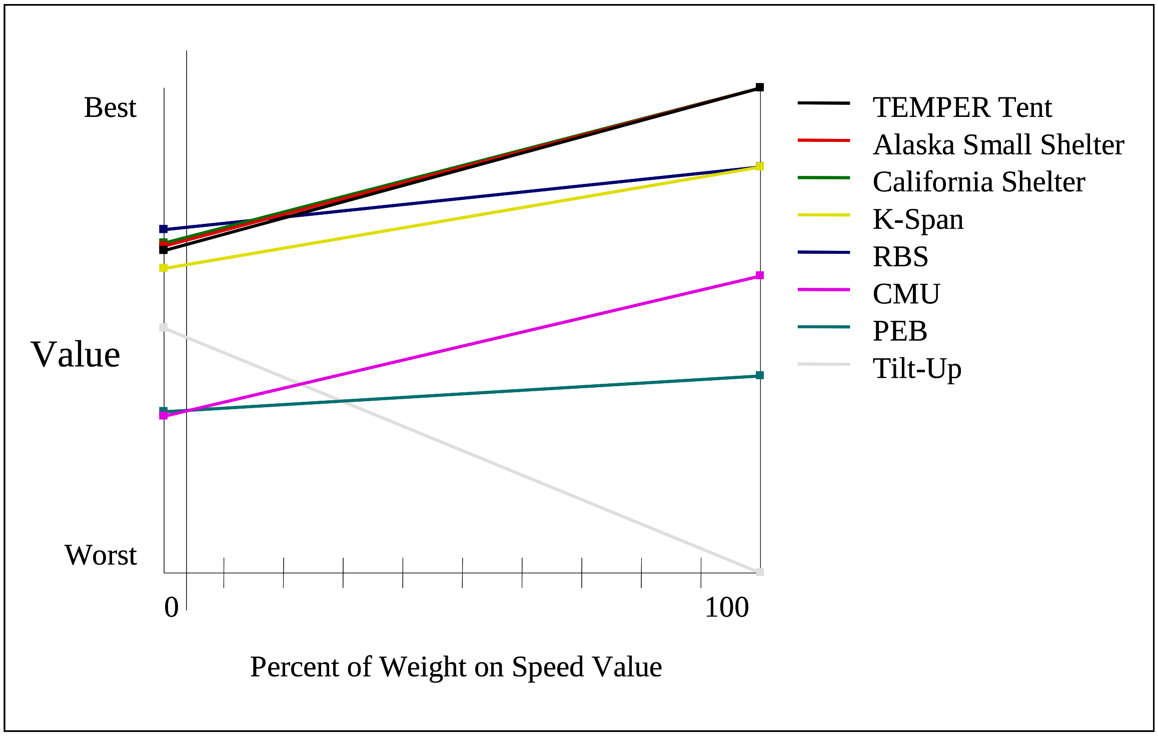


Figure 4.12. Sensitivity Analysis of Speed Value Objective

4.2.3 Sensitivity Analysis of the "Commercial Materials" Branch

"Commercial Materials" is the third highest weighted top-tier value with a global weight of 18.2%. Figure 4.13 shows the "Commercial Materials" branch along with its lower-tier values of "Cost" and "Delivery Time" with global weights of 12.1% and 6.1%, respectively.

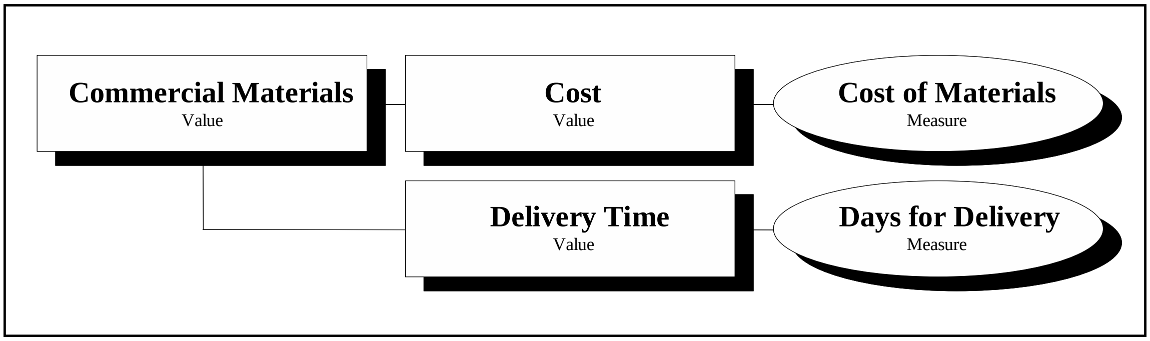


Figure 4.13. Commercial Materials Value Branch

Figure 4.14 shows the breakeven chart for the sensitivity analysis of "Commercial Materials." It indicates that RBS is the top-ranked alternative at the value's global weight of 18.2%. Furthermore, RBS remains the top-ranked alternative as long as the global weight of the "Commercial Materials" value remains at or below about 23%. If the global weight of this value exceeds about 23%, then TEMPER Tent and Alaska Small Shelter become the top-ranked alternatives, followed closely by California Shelter. If the weight of "Commercial Materials" increases to about 80%, then K-Span also becomes a better alternative than RBS. "Commercial Materials" is considered sensitive to weight increases. Additionally, CMU has the most negative slope for the "Commercial Materials" value, because of its higher cost and longer delivery time than any other alternatives. Tilt-up also performs poorly in this value for similar reasons.

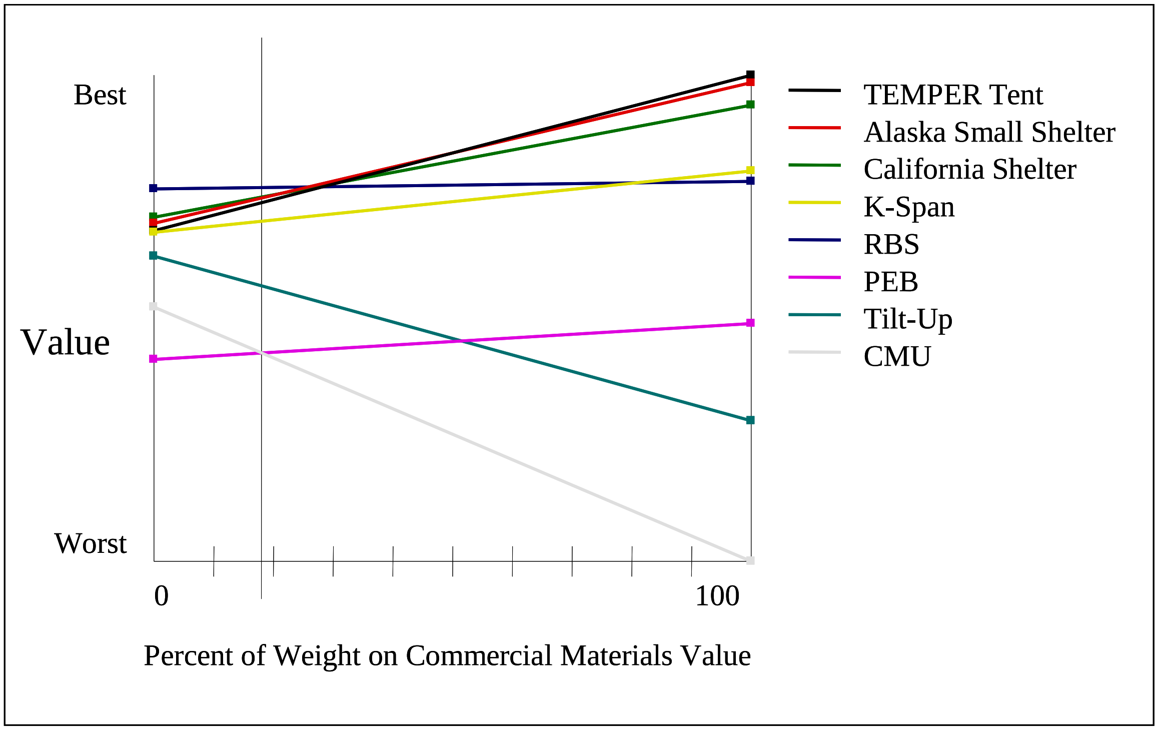


Figure 4.14. Sensitivity Analysis of Commercial Materials Value Objective

Since the "Commercial Materials" value was considered sensitive, sensitivity analysis was also performed on the second-tier values of "Cost" and "Delivery Time" to gain further insight into the sensitivity of this value branch. Figures 4.15 and 4.16 are the breakeven charts for the sensitivity analysis of these values, respectively. Figure 4.15 shows that when "Cost" is weighted at 12.1%, RBS is the best alternative. It remains the best alternative as long as "Cost" is weighted less than 25% of the total value within the model. Therefore, "Cost" is considered to be moderately insensitive. If the global weight for "Cost" increases to or exceeds 25%, then TEMPER Tent becomes the top ranked alternative followed very closely by Alaska Small Shelter and California Shelter. These alternatives are based on fabric type structures, which have lower costs; therefore, they are valued more as the weight of "Cost" increases. None of the other construction method alternatives surpass RBS regardless of the fluctuation of the "Cost" weighting. Notice that CMU has the only negative slope in this value. It had the highest cost per square foot estimate.

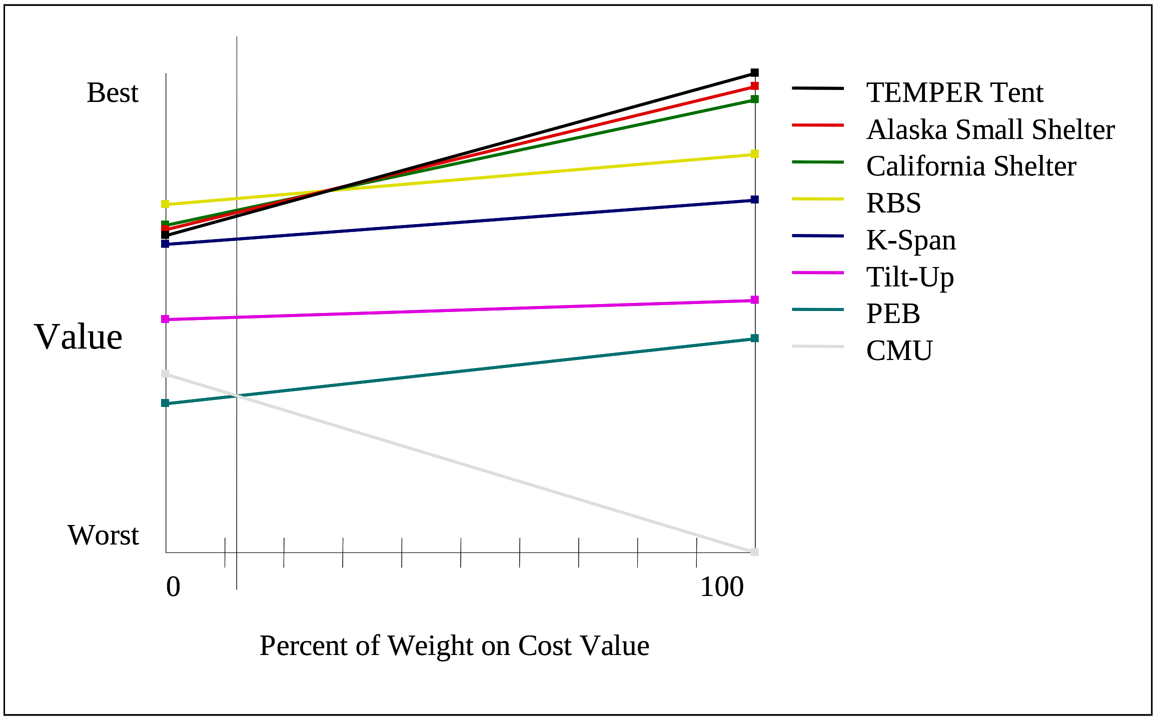


Figure 4.15. Sensitivity Analysis of Cost Value Objective

Figure 4.16 shows that when "Delivery Time" is weighted at 6.1%, RBS is the top-ranked alternative. It retains the top ranking as long as the global weight remains between 0% and 10%. If the current weight increases to 10% or more, Alaska Small Shelter and TEMPER Tent become the two best alternatives, followed closely by California Shelter. K-Span gains a higher ranking than RBS when the weight reaches about 26%. These alternatives are based on fabric type structures, which have faster delivery times; therefore, they are valued more as the weight increases. "Delivery Time" is moderately sensitive.

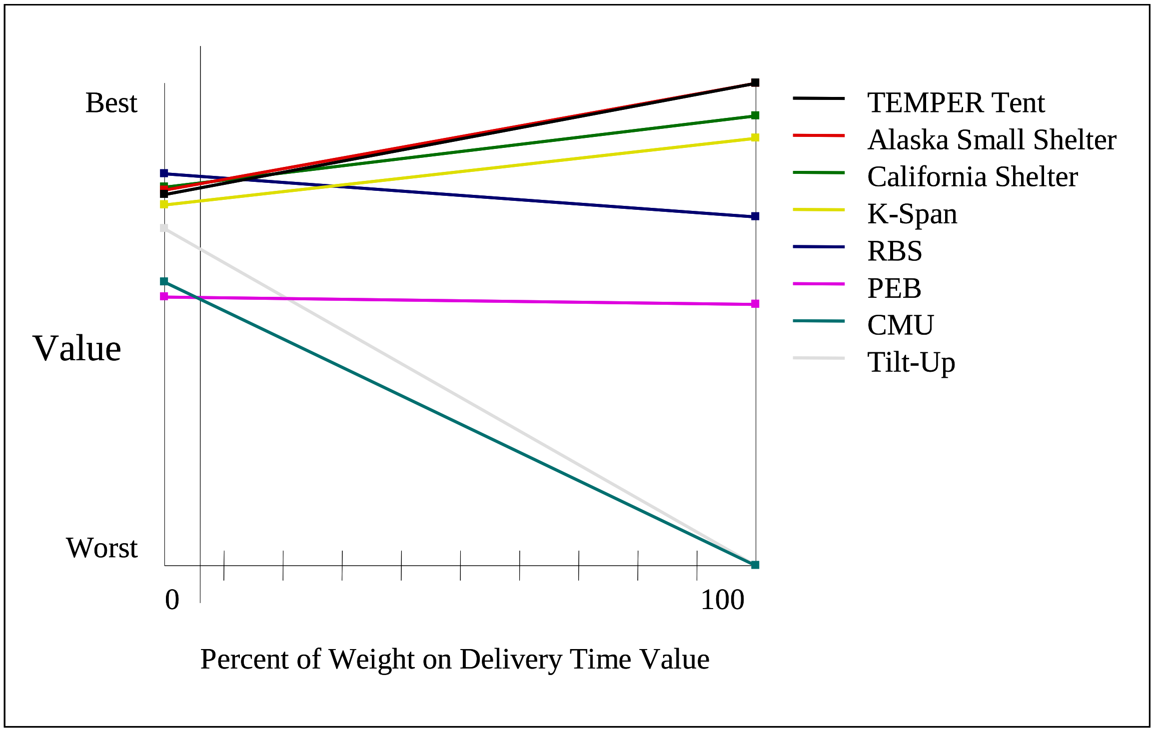


Figure 4.16. Sensitivity Analysis of Delivery Time Value Objective

4.2.4 Sensitivity Analysis of the "Force Protection" Branch

"Force Protection" is the fourth top-tier value in the hierarchy and has a global weight of 9.1%. As shown in Figure 4.17, the "Force Protection" value branch has two lower-tier values "Hardened" and "Insulation," which comprise 6.8% and 2.3%, respectively, of the total weight in the model.

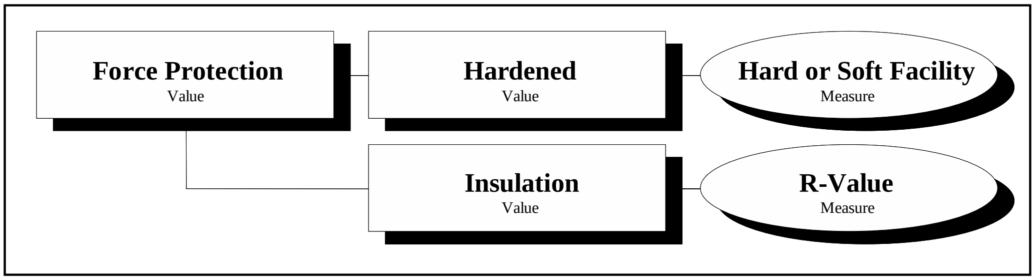


Figure 4.17. Force Protection Value Branch

Figure 4.18 shows the breakeven chart for the sensitivity analysis of the "Force Protection" value. When the global weight for "Force Protection" is 9.1%, RBS is the top-ranked alternative. It remains the top ranked alternative regardless of how much the weight for this value is increased. However, a slight decrease in the value's weight to about 8% results in Alaska Small Shelter, California Shelter, and TEMPER Tent replacing RBS as better alternatives. All three of these fabric type facility alternatives have strong negative slopes. Therefore, as the importance of "Force Protection" increases, these alternatives lose value quickly. Alternatively, it is obvious that RBS, Tilt-Up, and CMU, with their positive slopes, are the only alternatives whose values increase with the importance of "Force Protection." This value is sensitive.

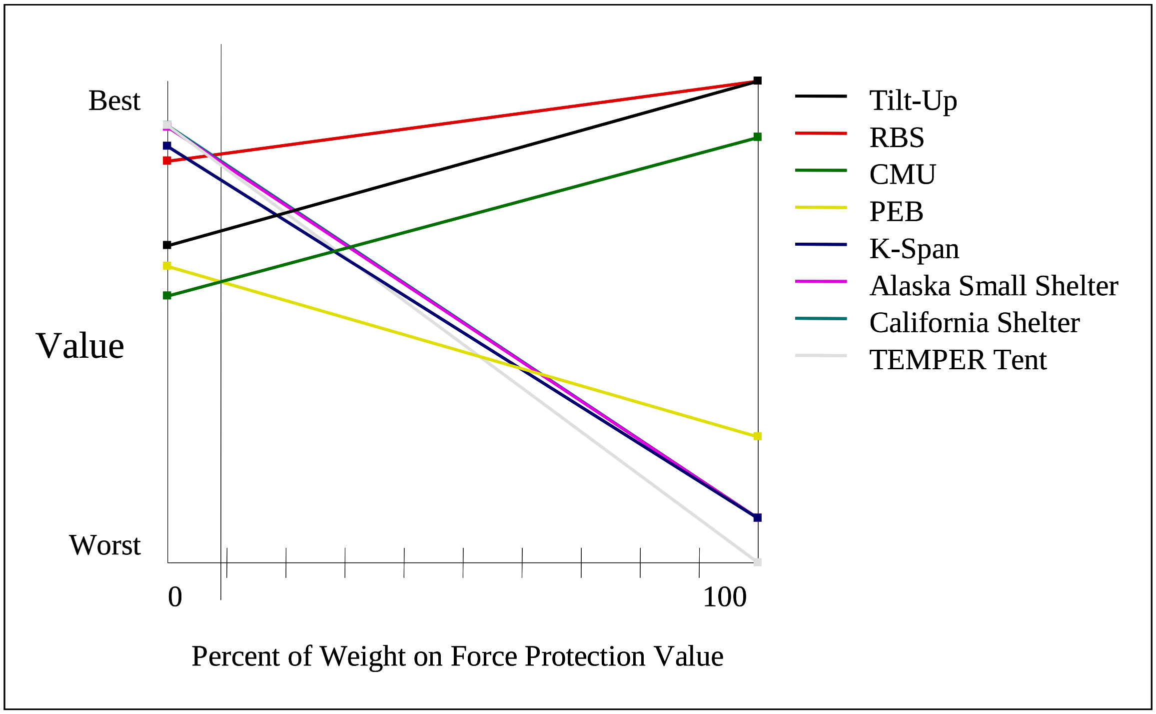


Figure 4.18. Sensitivity Analysis of Force Protection Value Objective

Since the "Force Protection" value was considered sensitive, sensitivity analysis was also performed on the second-tier values of "Hardened" and "Insulation" to gain further insight into the sensitivity of this value branch. Figures 4.19 and 4.20 are the breakeven charts for the sensitivity analysis of these values, respectively. Figure 4.19 shows a breakeven chart for the sensitivity analysis of the "Hardened" value, which closely resembles the breakeven chart for "Force Protection." The same observations stated for "Force Protection" also apply to the "Hardened" second-tier value. For instance, RBS is the top-ranked alternative at the current weight of 6.8% and remains the best alternative regardless of how much the "Hardened" value weight is increased. However, if the weight decreases to about 5%, Alaska Small Shelter, California Shelter, and TEMPER Tent become the better alternatives. Additionally, RBS, Tilt-Up, and CMU receive increasing valued as more importance is associated with the value.

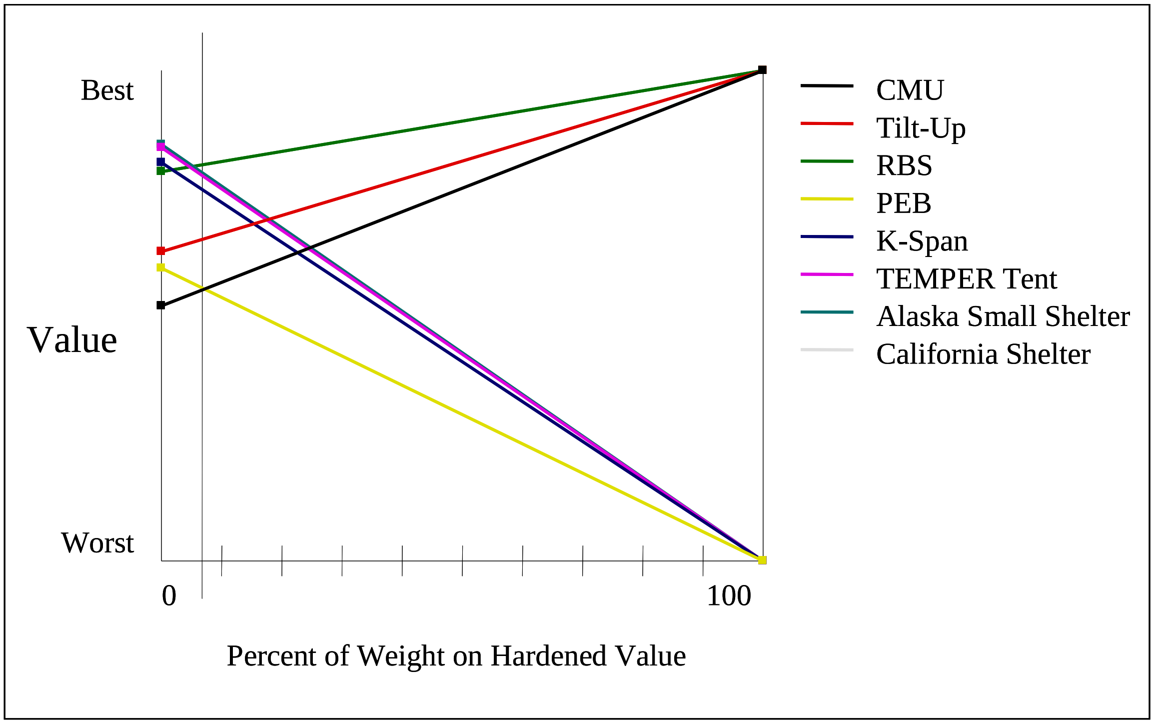


Figure 4.19. Sensitivity Analysis of Hardened Value Objective

A breakeven chart for the sensitivity analysis of the "Insulation" value is shown in Figure 4.20. "Insulation" initially had a global weight of 2.3%, the lowest value weighting in the hierarchy. RBS remained the top-ranked alternative when varying the weight from 0% to about 57%. Therefore, the "Insulation" value is considered insensitive and is unlikely to influence the decision.

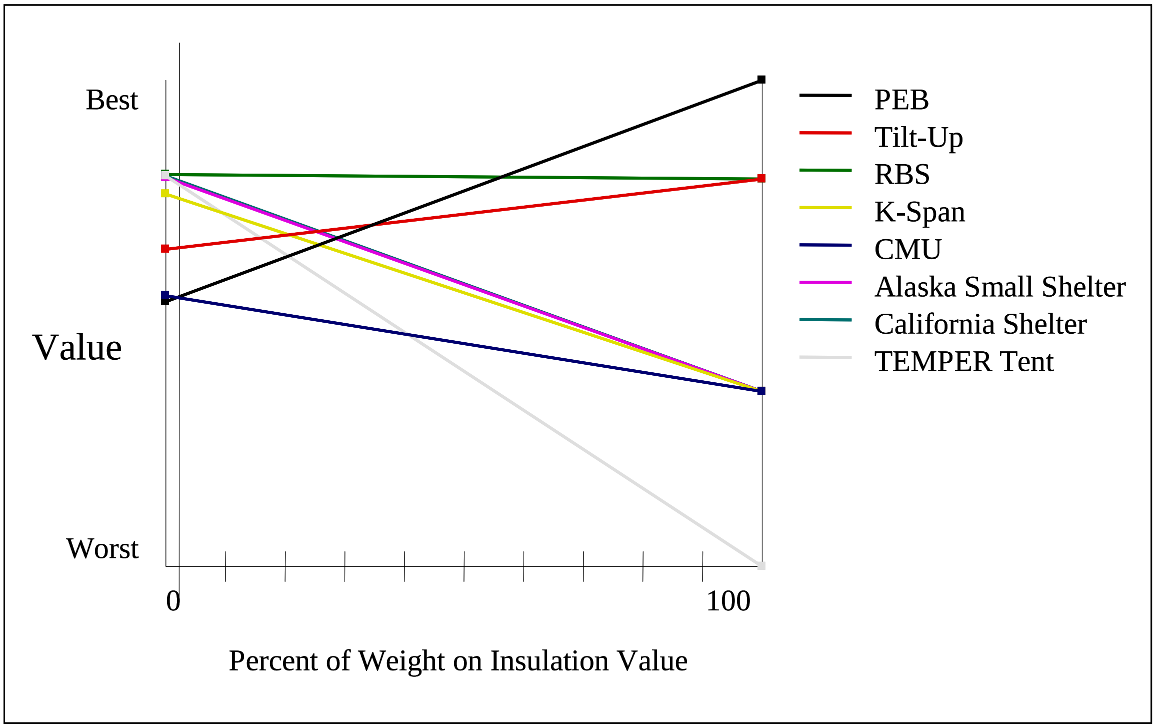


Figure 4.20. Sensitivity Analysis of Insulation Value Objective

4.2.5 Sensitivity Analysis of the "Military Transport" Branch

The "Military Transport" branch shown in Figure 4.21 contains only one second-tier value, "Pallet Positions." Therefore, regardless of how sensitive the "Military Transport" value might be, there is no need to perform sensitivity analysis on the "Pallet Positions" value. Figure 4.22 shows a breakeven chart for the sensitivity analysis of the "Military Transport" value. RBS is the top-ranked alternative at the current global weight of 9.1% for "Military Transport." Furthermore, it remains the top-ranked alternative regardless of the weight assigned to the value; therefore, the value is considered strongly insensitive.

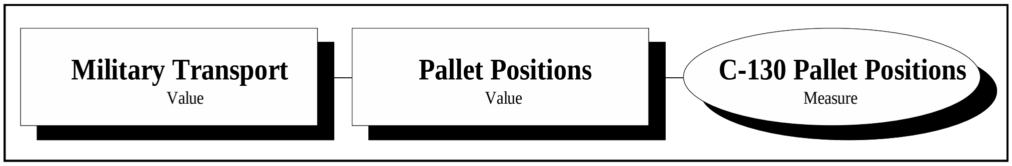


Figure 4.21. Military Transport Value Branch

Except for K-Span and PEB, all of the alternatives increase in value as the importance of the value increases. Because of the additional pallet positions required to transport their large steel sections, the values of K-Span and PEB decrease as "Military Transport's" value becomes more important.

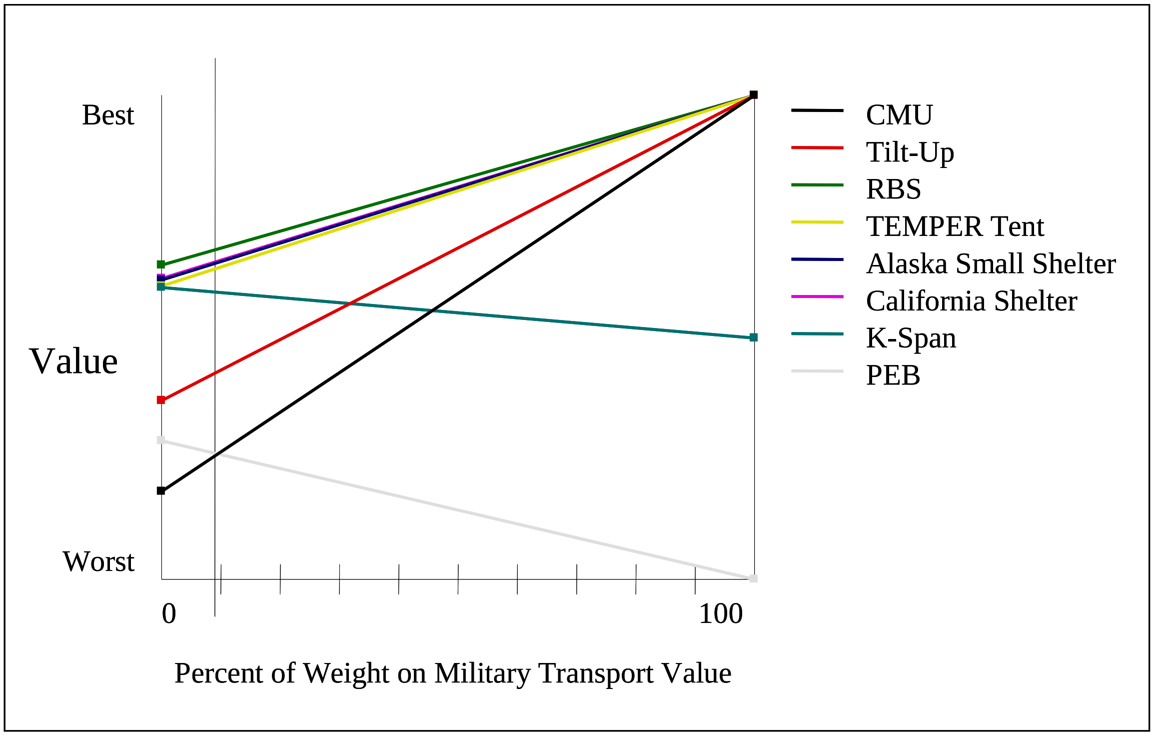


Figure 4.22. Sensitivity Analysis of Military Transport Value Objective

4.3 Summary

Chapter 4 presented and analyzed the results of the model's evaluation of eight construction method alternatives generated by RED HORSE engineers. The deterministic analysis showed that RBS achieved the highest total value score of 80.9%. The ranked alternatives were presented in stacked bar charts to show how each measure in the model contributed to the final scores of the alternatives. Finally, extensive sensitivity analysis was performed and explained to provide greater insight to the decision-maker regarding how the alternative rankings are affected by varying the weights of the value hierarchy.

5. Conclusions

This chapter provides conclusions and recommendations, step 10 in the VFT process (Shoviak, 2001), generated by this thesis. First, the research effort and results of the model are summarized. Next, the benefits of the value model for RED HORSE engineers are discussed. Last, recommendations are provided, and future research ideas are introduced.

5.1 Research Summary

The primary objective of this research effort was to determine if a value focused thinking (VFT) approach could benefit RED HORSE engineers in their decision effort to choose the optimal vertical construction method for a deployed contingency. The results presented and discussed in Chapter 4 show that applying the VFT decision analysis methodology does in fact provide RED HORSE with a viable decision tool, and this value model is an objective, defendable, repeatable process for the evaluation and selection of future vertical contingency construction methods. The VFT methodology explained in Chapter 3 described the iterative process by which the model-builder worked with the decision-maker to develop a top-down value model. The value hierarchy developed in this thesis captures what is important to RED HORSE engineers in choosing a deployed vertical contingency construction method. Further, by creating the evaluation measures and value functions and weighting the hierarchy, the value model is able to quantify the desires of the decision-maker in the form of ranked final value scores for multiple alternatives.

Once the value model had been created, the decision-maker was able to identify and generate data for eight potential construction methods for evaluation with the model. The eight alternatives chosen for evaluation presented a diverse group of construction methods available for RED HORSE implementation. Concrete Masonry Unit (CMU) construction is the most traditional of the alternatives chosen for evaluation, and Royal Building System's (RBS) stay-in-place plastic formwork with reinforced concrete construction is the latest and perhaps most innovative. Other innovative methods that were evaluated included tilt-up reinforced concrete construction, pre-engineered metal building (PEB) construction, and K-Span construction. The decision-maker already has significant experience with these methods in the field. Last, three fabric frame tent construction methods California Shelter, Alaska Small Shelter, and TEMPER Tent, all methods with proven success in military applications, were also evaluated. In the end, RBS achieved the highest total value score gaining 80.9% of the value available within the model. RBS seemed to perform consistently across the entire value hierarchy and scored value in every evaluation measure. RBS did particularly well in the "Force Protection" value branch. The detailed deterministic and sensitivity analysis discussed in Chapter 4 provides insight to the decision-maker on where this value was realized and how the weighting of the various value objectives within the hierarchy affected this outcome.

5.2 Value Model Benefits

The VFT decision analysis model provides several benefits to RED HORSE. First, the iterative process of collecting input on what the decision-maker values in choosing a contingency construction method and creating a value hierarchy based on those inputs has provided RED HORSE with a documented guide to their vertical construction value objectives. The top level value objectives within the hierarchy, specifically "Design," "Commercial Materials," "Military Transport," "Construction," and "Force Protection," and the other values and measures within those branches, directly relate to the RED HORSE Concept of Operations Plan (CONOPS) explained in AFI 10-209 (HQ AFCESA, 2001). RED HORSE units provide the Air Force with expedient, deployable, adaptable, and sustainable combat construction capabilities, and this value model incorporates that same philosophy into the selection of a contingency construction method.

Second, creating a top-down, objectives driven generic value model provides RED HORSE with a defendable and easily repeatable process for making future vertical contingency construction method decisions regardless of specific project requirements or beddown location details. Simply by adjusting the model's value weightings, RED HORSE can tailor this generic VFT model for any future contingency. The value model provides a clear and efficient method for evaluating future contingency construction alternatives, by quantifying the value score for how well an alternative performed the evaluation measures. This enables the objective evaluation of unlimited alternatives by their ability to achieve the fundamental objective. This is a distinct advantage over the currently used alternatives-driven decision process.

Last, the multiple-objectives driven VFT model promotes clear communication between RED HORSE and other agencies. Presenting this value model to commercial construction materials contractors or Air Force contracting officers can help show them what RED HORSE wants from a contingency construction method. This might be helpful in identifying or developing future construction methods with even greater value achievement than the alternatives evaluated in this thesis.

5.3 Recommendations

This research effort yielded two primary recommendations. First, Value Focused Thinking is a viable decision methodology for RED HORSE to use for selecting future contingency construction methods. RED HORSE engineers should consider applying the same value hierarchy to any future vertical contingency construction project, and simply tailor the model's value weightings to suit their needs for specific project requirements and deployed location environment. Second, RBS outscored seven other reliable and proven construction alternatives in the value model which the 820th RHS helped create. The benefits and limitations of this innovative construction method, its materials and technology, should be further investigated, and RBS should be immediately considered for application on future RED HORSE projects.

5.4 Future Research

Other areas of interest were generated by this thesis effort. First, the value model was limited to vertical construction methods. If the process of selecting a horizontal construction method for a contingency has the same characteristics of a complex decision, namely expediency, adaptability, deployability, and survivability, and the availability of multiple alternatives, then perhaps a value model for horizontal construction method selection could also be developed. Second, this value model could be field tested by using it to actually select a construction method for a future RED HORSE contingency project. The selection process could be monitored, and the decision could be evaluated by how well the chosen construction method meets actual project requirements. Does the chosen alternative actually meet RED HORSE value objectives specified within the model? Observations and results could be used to improve the value model for future decisions. Finally, the value model could be used to generate additional construction method alternatives. Perhaps it could be shared with commercial manufactures in an effort to create an even better alternative or improve the ones evaluated in this thesis.

Appendix A: Proxy Decision Team

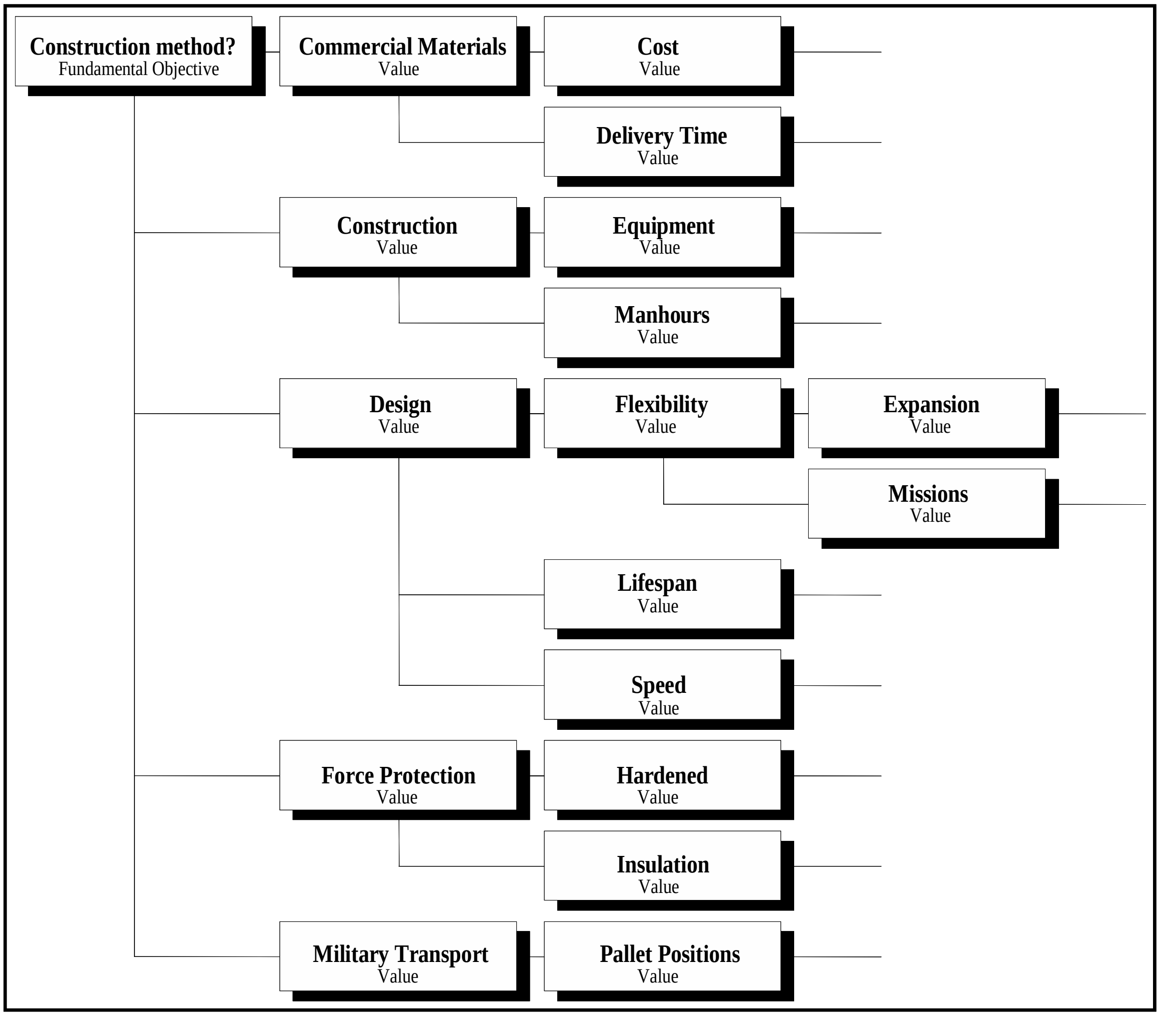
The following members of the 820th RED HORSE Squadron (RHS) served as the proxy decision team for developing the value model in this thesis.

Proxy Decision-maker	820th RHS Engineers, Nellis AFB
Decision Team Leader	Capt Mathew Meichtry, 820th Chief of Design
Decision Team Member	Maj Jarrett Purdue, 820th Engineering Flight Commander
Decision Team Member	Capt Clifford Theony, 820th Engineer
Decision Team Member	1Lt Todd Williams, 820th Engineer

Appendix B: Value Input Changes

As explained in Chapter 3, the model builder and RED HORSE engineers discussed the value inputs and decided that some were either redundant or unnecessary. According to Kirkwood, a value hierarchy should be as small as possible to facilitate communication with interested parties and require fewer resources to estimate the performance of potential alternatives (Kirkwood, 1997:18). The value hierarchy must also be complete, non-redundant, independent, and operable, so that the overall objective of the decision can be achieved (Kirkwood, 1997:16-18). Thus, the following changes were made to the value inputs to create the complete and operable value hierarchy shown at the end of this appendix.

First, under construction, "construction time" was eliminated, since the man-hours value would capture the same time of construction measurement. Second, under materials, "availability" was deleted, since the 820th RHS can assume that every potential construction alternative worthy of consideration has to be fully available for procurement by the Air Force. In its place, "delivery time" was moved from transportability to materials. Third, under safety/protection, "weather" was removed, since the "force protection" value would already consider the strength of a construction method, and a second value for wind load was deemed repetitive. Fourth, "environmental controls" was also deleted from under safety/protection, because this value would not differentiate between possible decision alternatives. The RED HORSE engineers decided that any construction alternative would be environmentally controllable. In its place, the value of "insulation" was added, because this captured another value objective that would vary between alternatives. Next, under transportability, "transportation cost" was eliminated, because the cost for delivery would already be included within the materials cost value. Finally, “transportability” was changed to “military transport” and the value of “weight” was deleted. The “weight” value was removed, since the “pallets” value would consider both the size and weight of materials in transport. The value input changes was an iterative process which took place over multiple rounds of discussions.



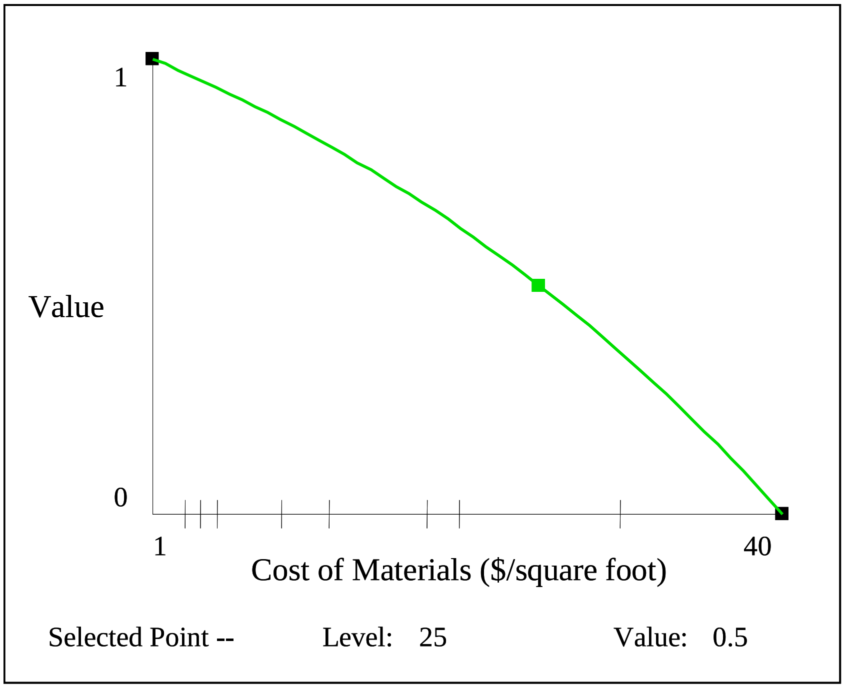
Appendix C: Evaluation Measures and Single Dimensional Value Functions (SDVF)

Commercial Materials Measure: Cost of Materials

Global Weight: 12.1%

Value	Measure	Definition
Cost	Cost of Materials	Total cost for RED HORSE to purchase this construction method from the vendor. Includes the cost of all materials and transportation of those materials from the vendor to RED HORSE.

SDVF:

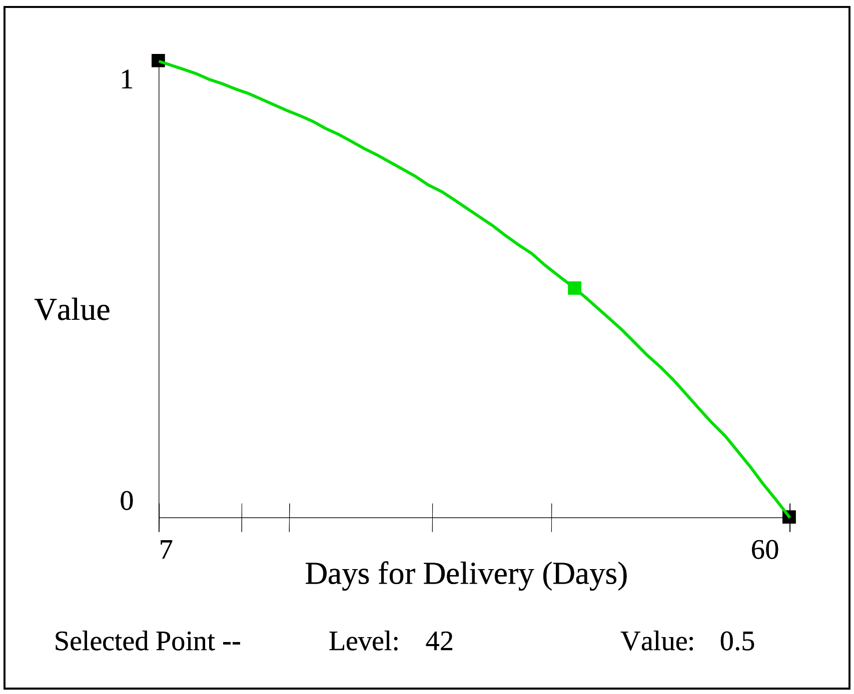


Commercial Materials Measure: Days for Delivery

Global Weight: 6.1%

Value	**Measure**	**Definition**
Delivery Time	Days for Delivery	Time it takes the construction materials to reach RED HORSE after being ordered from the commercial vendor.

SDVF:



Construction Measure: Heavy Equipment

Global Weight: 9.1%

Value	Measure	Definition
Equipment	Heavy Equipment	Type and amount of heavy equipment pieces required to support this construction method.

SDVF:

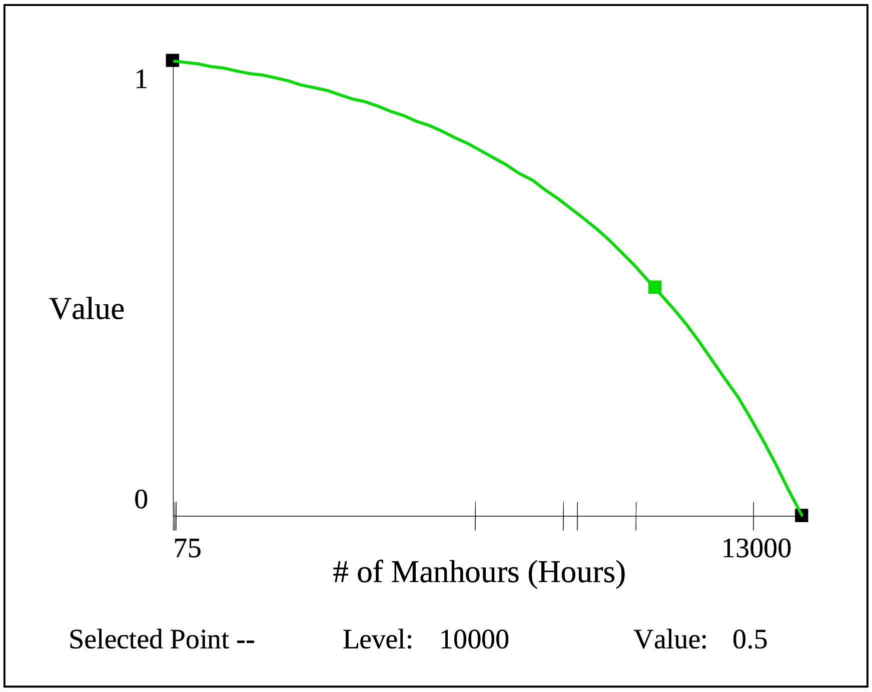
Label	Value
None Required	1.000
Within RHS Equipment Set	0.750
Beyond RHS Equipment Set	0.250

Construction Measure: # of Manhours

Global Weight: 27.3%

Value	Measure	Definition
Manhours	# of Manhours	Number of manhours required to construct a facility of at least 3,000 square feet with this construction method.

SDVF:

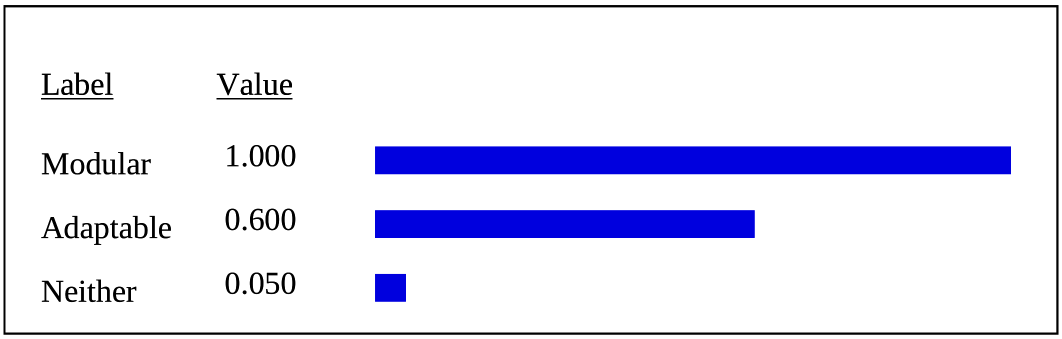


Design Measure: Size Adaptable

Global Weight: 5.2%

Value	**Measure**	**Definition**
Expansion	Size Adaptable	Ability to site adapt this construction method at deployed location to either increase or decrease the footprint of the facility.

SDVF:



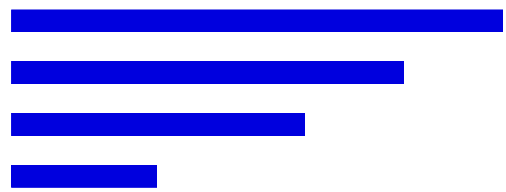
Design Measure: # of USAF Missions

Global Weight: 10.4%

Value	Measure	Definition
Missions	# of USAF Missions	Various types of USAF missions this construction method can accommodate.

SDVF:

Label	Value
Aircraft, Vehicles, Warehouse, Offices, and Lodging	1.000
Vehicles, Warehouse, Offices, and Lodging	0.800
Warehouse, Offices, and Lodging	0.600
Offices and Lodging Only	0.300



Design Measure: Years of Service

Global Weight: 7.8%

Value	Measure	Definition
Lifespan	Years of Service	Number of years of service this facility type is expected to provide at deployed location with minimal user maintenance.

SDVF:

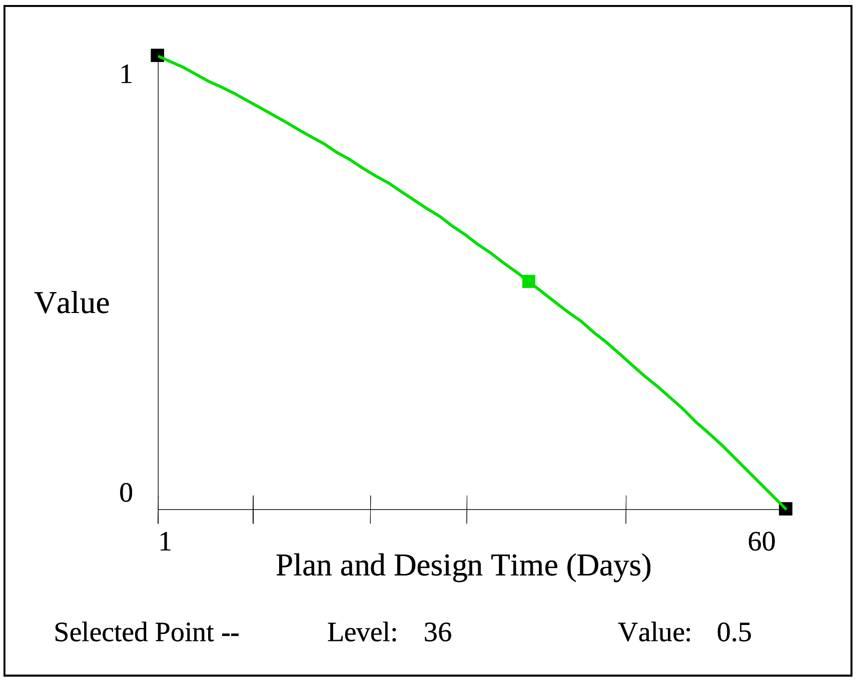
Label	Value
Permanent (>= 25 years)	1.000
Semi-Permanent (5 < X < 25 years)	0.700
Temporary (<= 5 years)	0.400

Design Measure: Plan and Design Time

Global Weight: 3.9%

Value	Measure	Definition
Speed	Plan and Design Time	Time it takes the RED HORSE design team to plan and design the facility using this construction method.

SDVF:

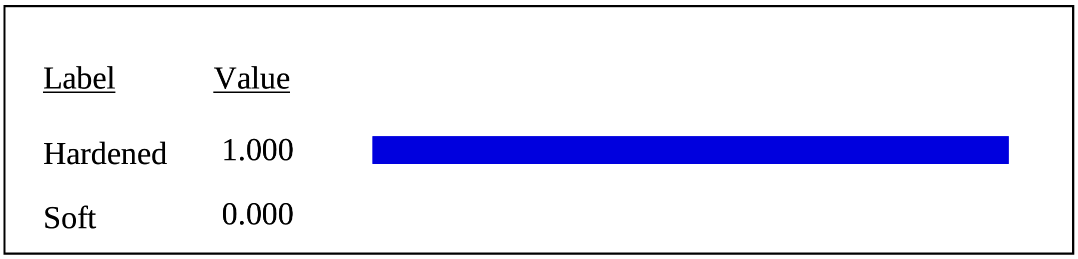


Force Protection Measure: Hard or Soft Facility

Global Weight: 6.8%

Value	**Measure**	**Definition**
Hardened	Hard or Soft Facility	Ability of this facility type to provide force protection against enemy attack.

SDVF:

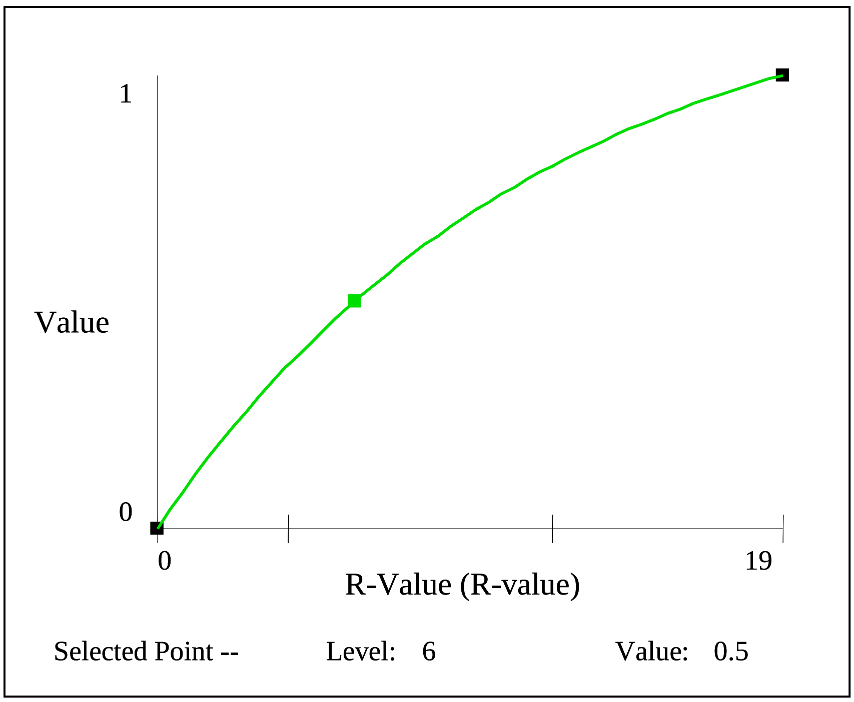


Force Protection Measure: R-Value

Global Weight: 2.3%

Value	Measure	Definition
Insulation	R-Value	The R-Value of the construction method (Level of thermal insulation inherent to this type of facility).

SDVF:



Military Transport Measure: C-130 Pallet Positions

Global Weight: 9.1%

Value	**Measure**	**Definition**
Pallet Positions	C-130 Pallet Positions	Number of USAF C-130 aircraft standard pallet positions required to transport this construction method's materials further downrange from vendor delivered location.

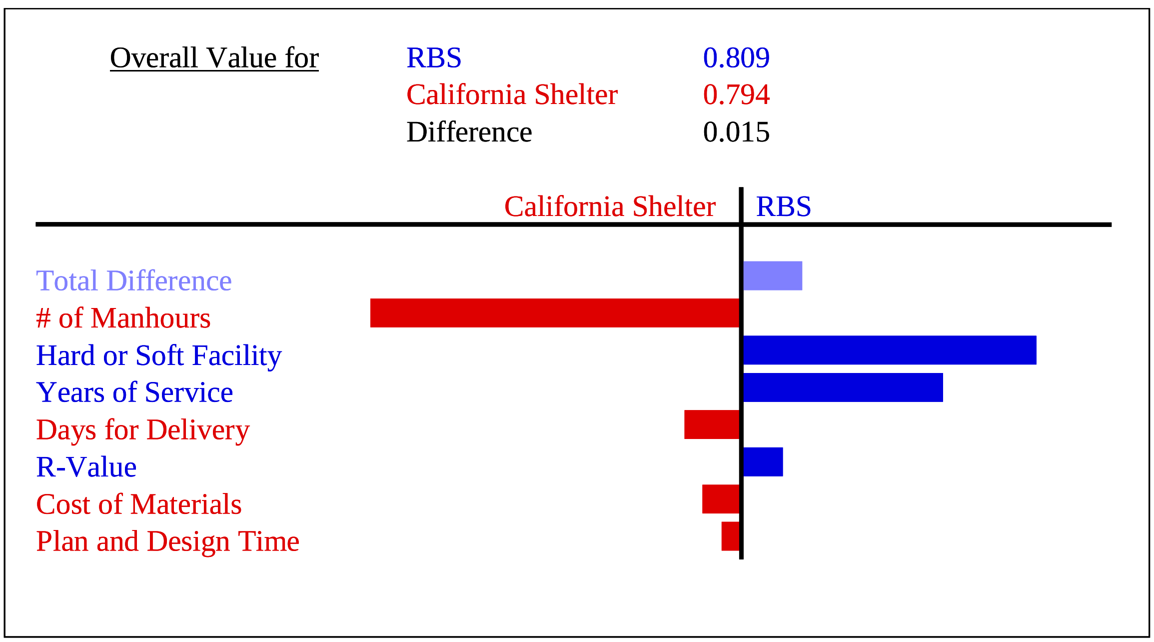
SDVF:

Label	Value
<= 4 (1 Aircraft)	1.000
4 < X <= 8 (2 Aircraft)	0.700
8 < X <= 12 (3 Aircraft)	0.400
12 < X <= 16 (4 Aircraft)	0.100
> 16 (More than 4 Aircraft)	0.000

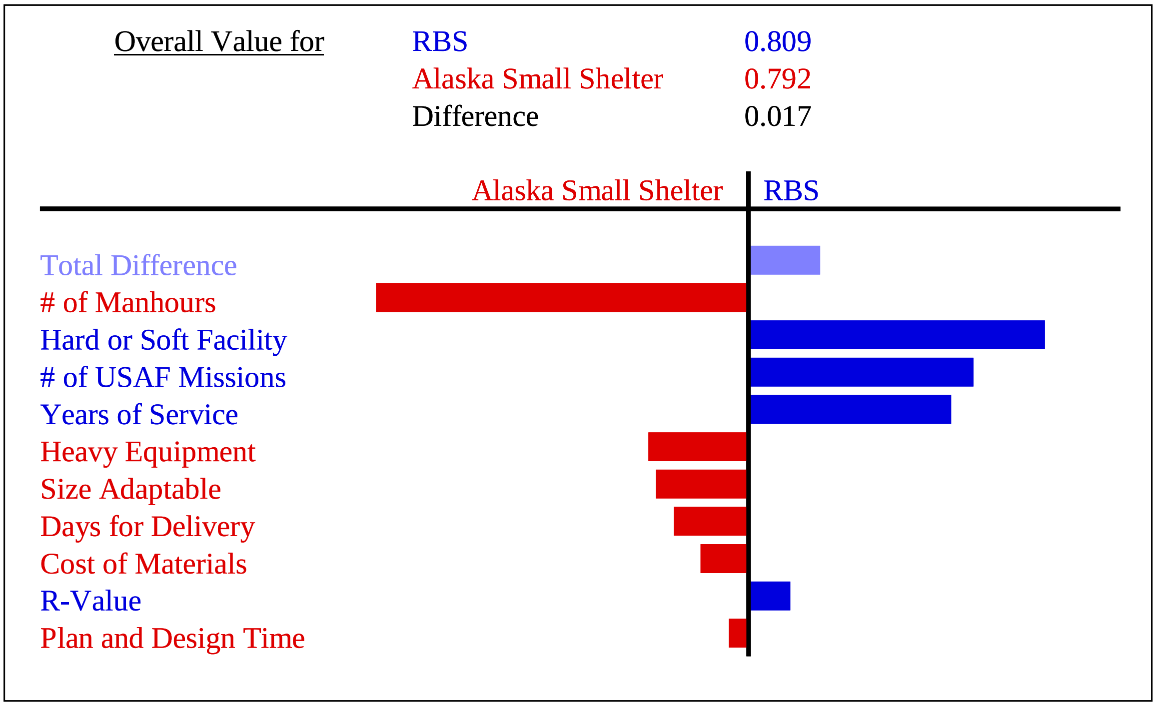
Appendix D: Value Score Comparison Charts

The following charts individually compare the value scores for the top ranked alternative RBS with the other seven alternatives. The seven alternatives are shown in descending ranking order by total value score. The measures in which RBS achieved greater value are indicated in blue, and the measures in which the other alternative achieved greater value are indicated in red. The measures are shown in descending order by global weight, and measures in which RBS and the alternative achieved the same value are not listed.

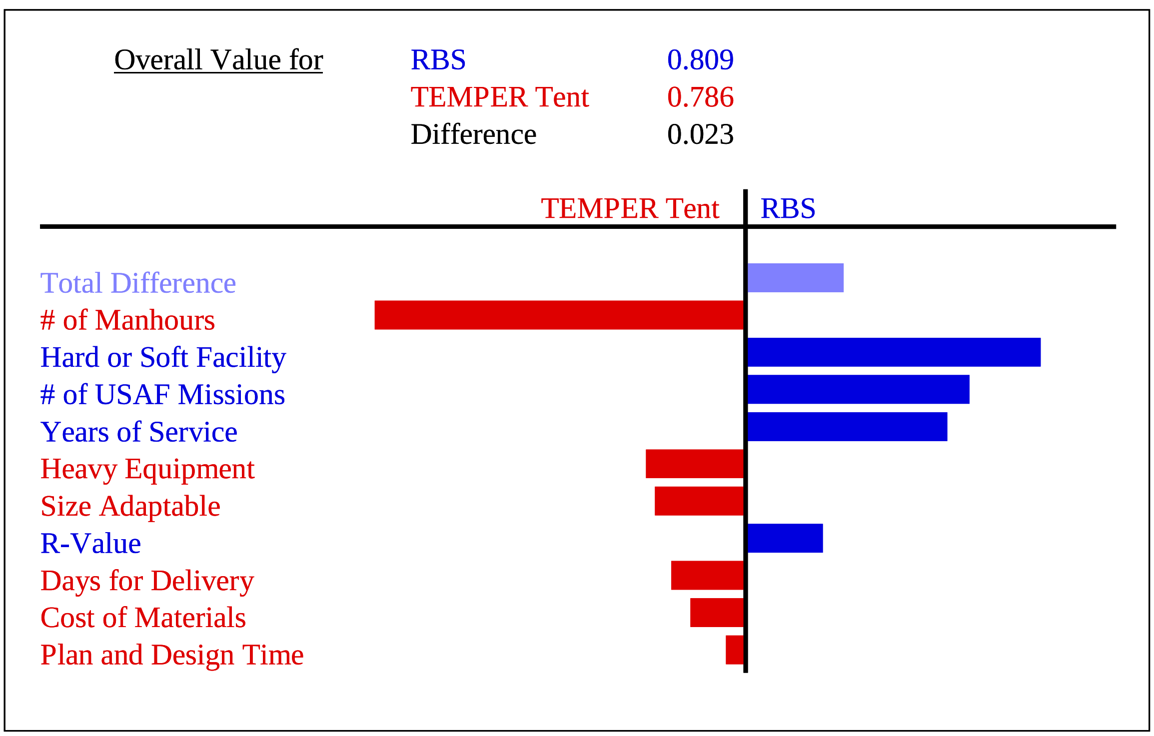
RBS versus California Shelter:



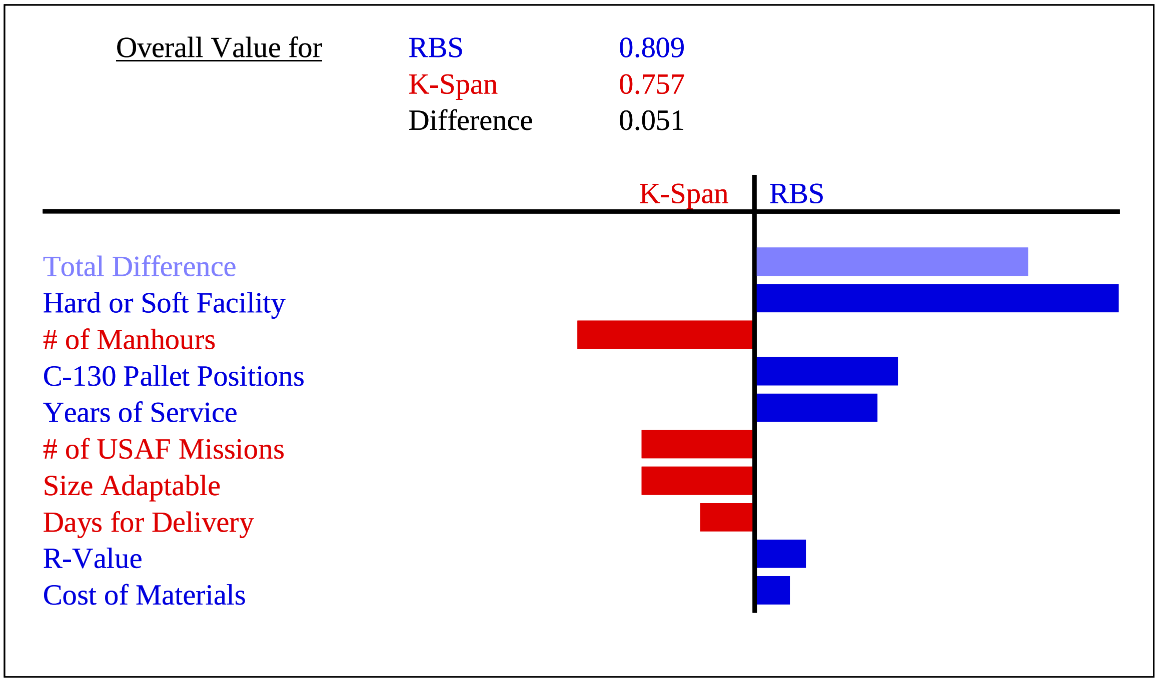
RBS versus AKSSS:



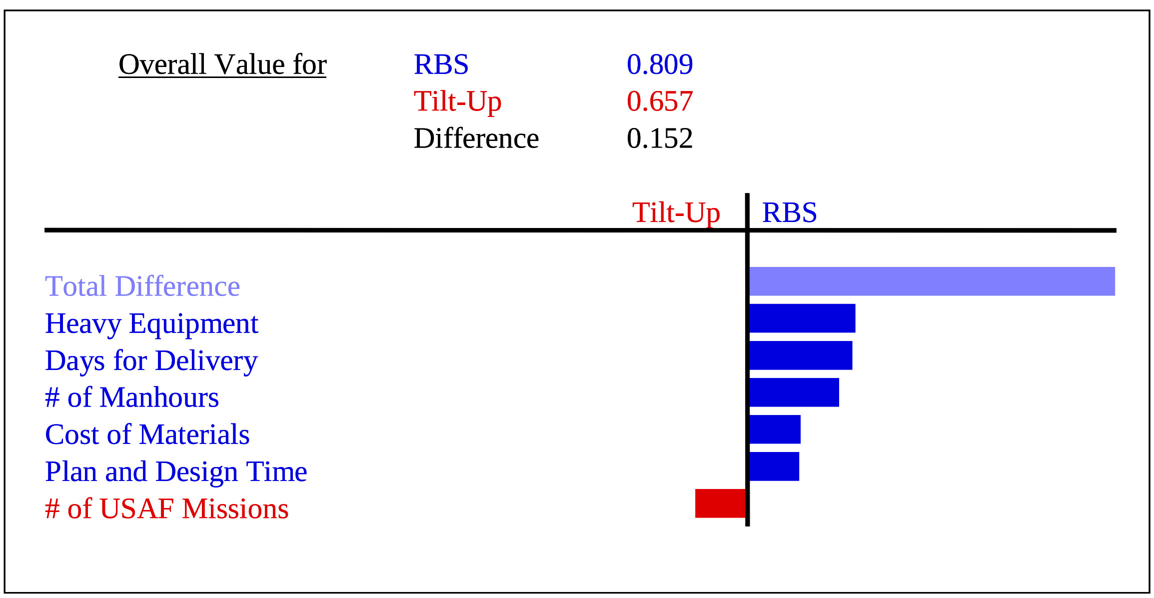
RBS versus TEMPER Tent:



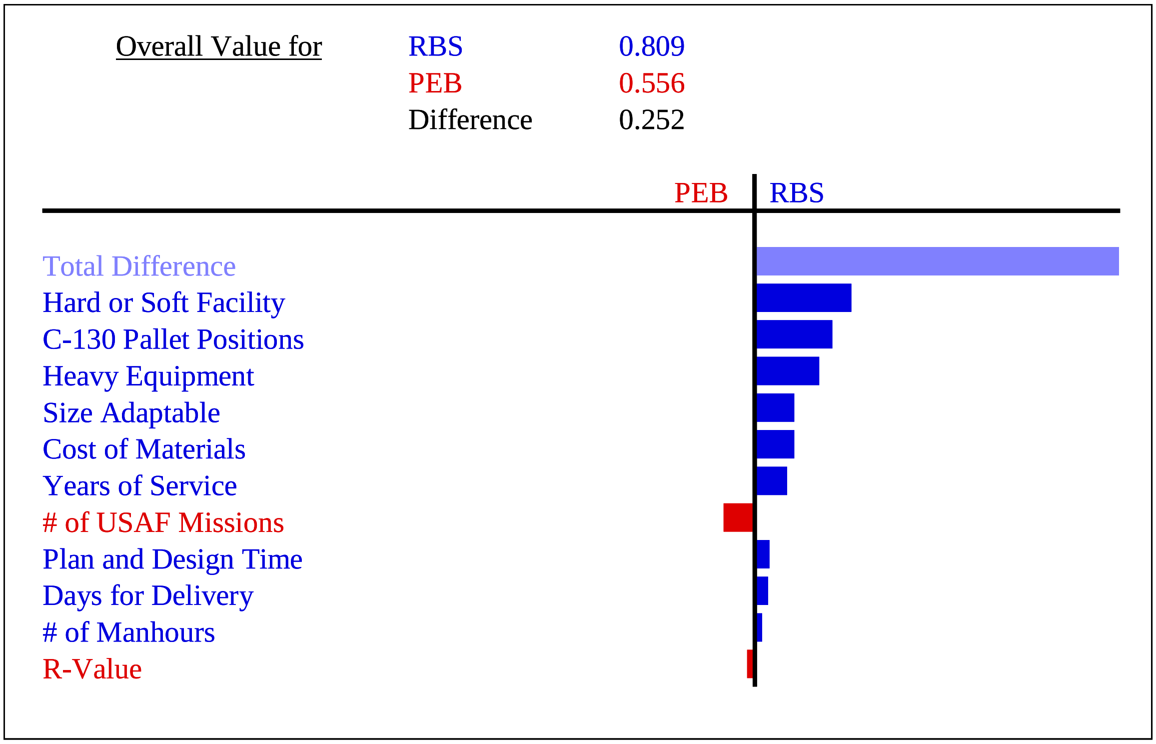
RBS versus K-Span:



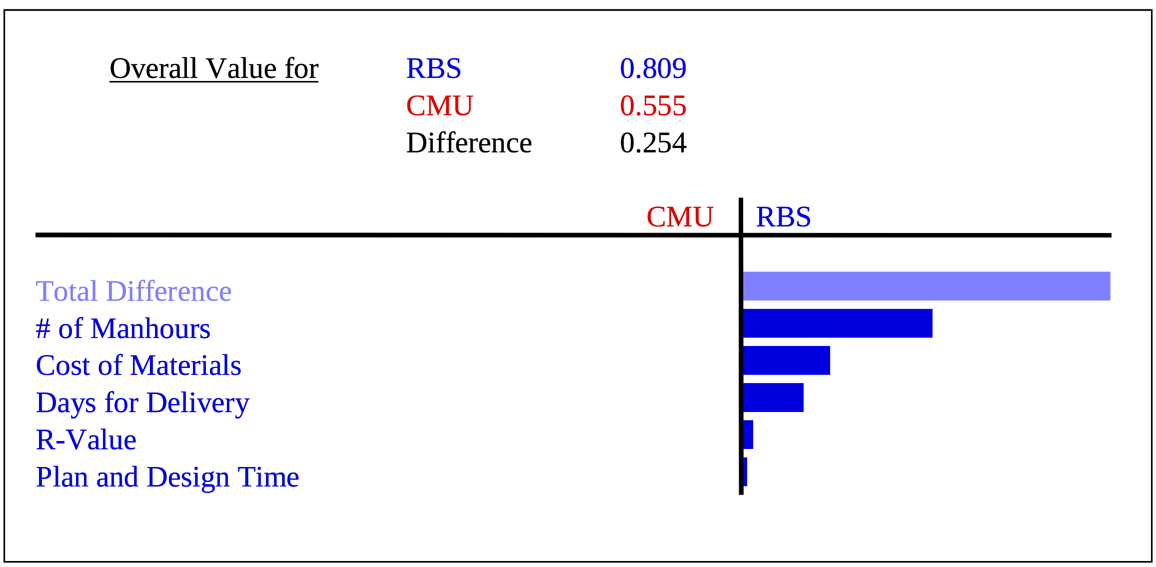
RBS versus Tilt-Up:



RBS versus PEB:



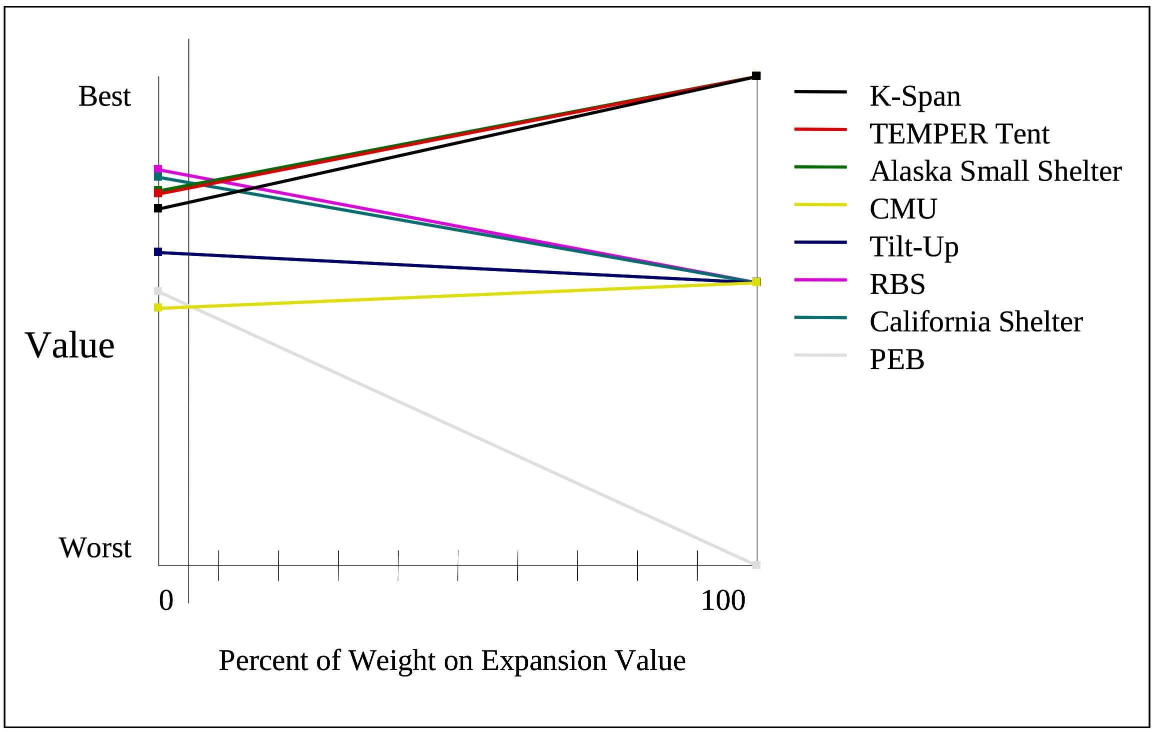
RBS versus CMU:



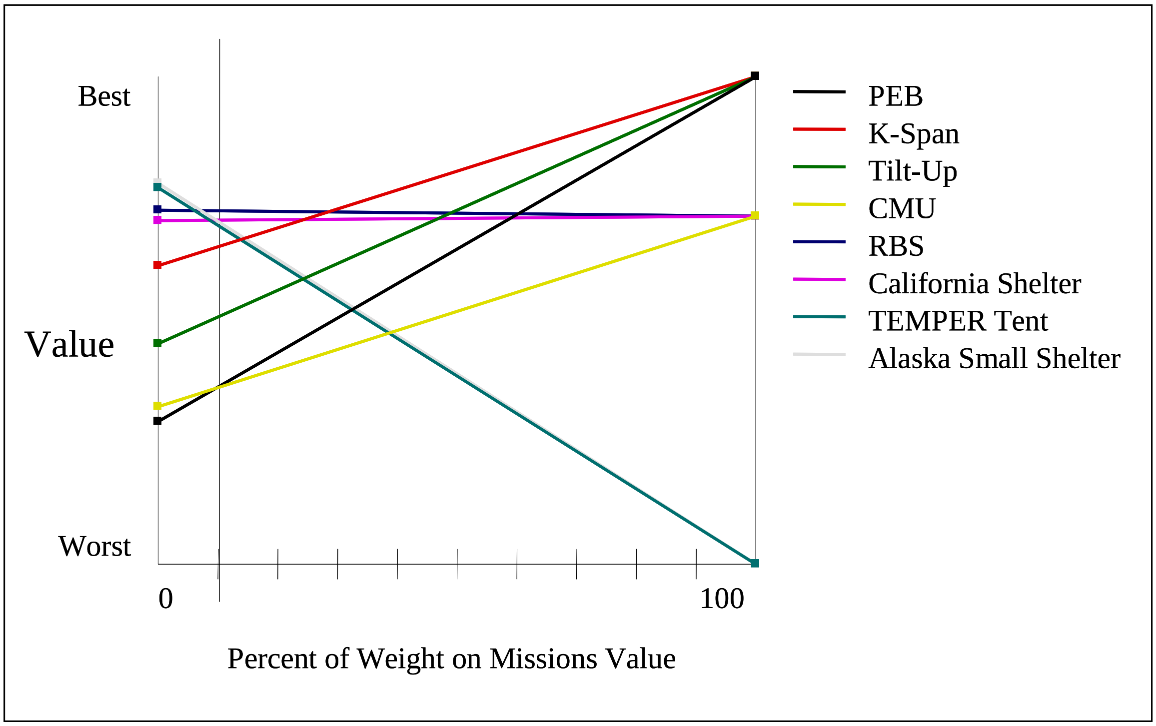
Appendix E: Additional Sensitivity Analysis

Sensitivity analysis was performed on the value model and explained in detail in Chapter 4. Since the second-tier value objective "Flexibility" was considered moderately insensitive, the sensitivity analyses for its third-tier values "Expansion" and "Missions" were not discussed. The breakeven charts for the sensitivity analysis of "Expansion" and "Missions" are shown here.

Expansion Value:



Missions Value:



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Vita

Major John Tryon graduated from Cypress Creek High School in Houston, Texas. He entered undergraduate studies at Tulane University, New Orleans, Louisiana where he graduated with a Bachelor of Science degree in Civil Engineering in May 1994. That same month, he was commissioned through the Air Force Reserve Officer Training Corps at Tulane University, Detachment 320.

Major Tryon's first assignment was with the 42nd Civil Engineer Squadron at Maxwell Air Force Base (AFB), Alabama in September 1994. There he worked in the engineering flight as a base programmer, design engineer, and construction project manager. In June 1998, he was sent to the South Pacific where he was assigned as the Readiness Flight Commander for the 36th Civil Engineer Squadron at Andersen AFB, Guam. After leaving Guam, Major Tryon attended Squadron Officer School at Maxwell AFB enroute to his next assignment with Headquarters United States Air Forces Europe (HQ USAFE) at Waterbeach, England. From July 2000 through July 2003, he served as HQ USAFE's North Atlantic Treaty Organization (NATO) construction program manager for the United Kingdom and Spain.

Major Tryon entered the Engineering Management program within the Graduate School of Engineering and Management, Air Force Institute of Technology (AFIT), Wright-Patterson AFB, Ohio, in August 2003. During his graduate engineering program, he also completed Air Command and Staff College in-residence at AFIT. Upon graduation, he will join the civil engineering directorate of Headquarters Air Mobility Command at Scott AFB, Illinois.

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14. ABSTRACT

Rapid Engineering Deployable, Heavy Operational Repair Squadron, Engineer (RED HORSE) Squadrons are 400-person, self-contained, combat engineer units that provide deployable and flexible expert construction capability for the United States Air Force. To help meet Air Force mission requirements, RED HORSE units currently employ a variety of traditional and innovative construction methods. But their alternatives-focused decision analysis approach to method selection limits their decision to known alternatives and may not fully achieve all of their objectives.

This research developed a generic value-focused thinking (VFT) decision analysis model to help RED HORSE evaluate and select contingency construction methods. Eight alternatives were generated and evaluated using the model, and Royal Building System's stay-in-place plastic formwork method achieved the highest total value score for the weights assigned to the value hierarchy. Deterministic and sensitivity analysis were performed on the value model results, and conclusions and recommendations were discussed.

This research showed that VFT is a viable methodology for contingency construction method selection. The value model captured RED HORSE objectives and used their values as the basis for evaluating multiple construction method alternatives. The alternatives' value score ranking results were objective, defendable, and repeatable, and the value model is highly adaptable for future contingency implementation.

15. SUBJECT TERMS

Contingency Construction, Construction Methods, RED HORSE, 820th RED HORSE Squadron (RHS), Value Focused Thinking (VFT), Value Model, Decision Analysis, Deterministic Analysis, Sensitivity Analysis

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